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AN ABSTRACT BIBLIOGRAPHY OF STATISTICAL METHODS IN RANGE AND RELATED PASTURE RESEARCH

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INTRODUCTION

This bibliography is the result of a project started by the Forest Service in the fall of 1957. As background for this project, literature was searched for published information relating to research methods and techniques and experimental designs applicable to range management studies. Several abstracting sources and a large number of scientific journals were consulted. An extensive file of references to pertinent literature citations was made up; abstracts were included for most of these references.

Because of numerous requests from the field and in view of the proposed servicewide conference on techniques to be held in 1961, it was decided to process a selected list of these abstracts for distribution to range and wildlife habitat research personnel in the Forest Service. The reference list is admittedly incomplete. Also much bibliographic checking against original sources remains to be completed. Any notices of omissions, corrections, or criticisms would be appreciated.

The Intermountain Forest and Range Experiment Station generously contributed typing, editing, and processing of the bibliography.

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PART I

I. THE MEASUREMENT OF VEGETATION

Ahlgren, H. L.
1947. a comparison of methods used in evaluating the results of pasture research. Amer. Soc. Agron. Jour. 39(3): 240-259.

The nature and complexity of problems associated with pasture research and the many variations in vegetative cover resulting from differences in soil, climate, topography, and elevation within and between regions have resulted in the development of a large number of widely different methods, all having as their common objective the evaluation of pasture research. Sixteen methods or techniques which have been or are being used are reviewed and their respective advantages and limitations are considered. Seven of these procedures, namely, hay weights, yields of dry matter of immature forages, photographs, surveys, botanical composition, chemical composition, and duration of grasses, do not involve the use of livestock; nine of the methods, including profit, production of milk, cattle and sheep weights, pilot plots, total digestible nutrients, carrying capacity, palatability trials, digestion trials, and biological assays with small animals, are based on results provided by livestock. Although fewer in number, methods of measurement which do not involve livestock are more commonly used than those based on livestock. Procedures which are not based on the use of livestock probably provide less accurate results than those involving livestock. They are frequently necessary, however in initial phases of pasture investigations where, of necessity, a large number of variables are included. There is need for additional studies designed to determine relationships between chemical composition, biological assays with small animals, and large farm animals. Research workers have generally failed to interpolate results in terms which are readily understood and enthusiastically accepted by farmers. Results provided in trials involving livestock are more readily expressed as cash values than those obtained by other procedures.

_______, Bohstedt, G., and Aamodt, O. S.
1938. problems in evaluating pastures in relation to other crops. Amer. Soc. Agron. Jour. 30(12): 1020-1029.

Thirteen methods used in the eastern part of the United States in evaluating pasture crops are reviewed. The need for, and desirability of, developing a satisfactory standardized technique for evaluating various types of pasture crops in relation to each other and to other harvested feed crops is discussed.

Alehin, V. V., and Uranov, A. A.
1933. methods of steppe analysis. Sovet. Bot. [Moskva] (2): 44-66.

Steppes, usually regarded as forage and pasture lands, possess a number of special features affecting the methods of their investigation. The most typical are (1) the abundant floral composition gradually decreasing southwards from 70-50 species to 12 species per square meter, (2) the complexity of the composition of horizontal tiers of swards, (3) characters of ecotypes and sinusium, and (4) the frequency of phenological changes. In conjunction with this, the application and size of sampling and the methods of recording associations and frequency of species in the swards are discussed in detail.

Australia. Council for Scientific and Industrial Research.
1946. grazing management: continuous and rotational grazing by merino sheep. 1. a study of the production of a sown pasture in the australian capital territory under three systems of grazing management. appendix: the measurement of pasture yield under grazing. 2. the effect of continuous and rotational grazing on the infestation of sheep with internal parasites. 3. a note on pasture management. Austral. Council Sci. and Indus. Res., Bul. 201, 104 pp.

A permanent pasture mixture of Phalaris tuberosa, Trifolium subterraneum, Medicago sativa, and Dactylis glomerata was seeded in 1939 at Canberra and grazed by Merino wethers from June 1940 to October 1944, according to three systems of grazing: continuous, 4-week, and 8-week rotation. The three systems were compared on the basis of yield and composition of the pasture and the live weight, wool production, and health of the grazing sheep. The carrying capacity of the pasture varied from 2 to 4 sheep per acre and averaged 2.84 sheep per acre over the 4-year period. The yield of P. tuberosa and T. subterraneum was not affected by the method of grazing at any time. However, by the end of the 4-year period, M. sativa had almost completely disappeared under continuous grazing. On the 4-week rotation the stand was considerably reduced over the same period. A productive stand was maintained on the 8-week rotation. The live weight of the sheep was equal on each of the three treatments except during the summer and autumn drought of 1942. There were no differences in the quality or quantity of wool grown by the three groups of sheep except in the 1941-1942 season because of the 6 months drought. The sheep on the 8-week rotation produced fewer tender fleeces and slightly more wool than the sheep on the other two treatments during this period. It is recommended that lucerne be grown as a separate crop. The obvious conclusion is drawn that unless the rate of stocking can be adjusted to the carrying capacity of the pasture, no increases in yield can be expected from rotational as compared with continuous grazing. Chemical analyses were made of the four pasture species under the three systems of grazing. The usual seasonal variations and variations due to available moisture were noted. The overall picture showed no substantial differences between the three systems of grazing. The measurement of pasture yield under the three systems of grazing and a study of the botanical composition and density were also made to see if there was

correlation. A study was made on the effect of continuous and rotational grazing on the infestation of sheep with internal parasites, the three most common nematodes. Analyses were made of egg counts from weekly fecal examinations. Conditions for transmission for Haemonchus contortus and Trichostrongylus species were favorable in the continuously grazed areas and unfavorable in the areas rotationally grazed bi-monthly. The infestations with Chabertia ovina were so slight that no analysis was made. Parasitism had no demonstrable effects on body weight or total wool weight. Rotational grazing did not favor the development and persistence of infectation with two of the three nematodes studied.

Becking, R. W.
1957. the zürich-Montpellier school of phytosociology. Bot. Rev. 23(7): 411-488.

The author holds that insufficient attention has been paid in the U.S.A. to the views and techniques of the European phytosociological school. With a view to prompting an inquiry into the value of European methods for studying vegetation in the U.S.A., a detailed description is given of the views and methodology of European phytosociological schools, particularly the Zürich-Montpellier school. The Physiognomic-Ecological, the Russian and the Uppsala schools are discussed, briefly. Aspects of the methodology of the Zürich-Montpellier school reviewed include: general vegetation concepts, plot analysis, the synthesis of vegetation units, phytosociological nomenclature, the use of statistics in vegetation analysis, and some viewpoints on, and criticisms of, the Zürich-Montpellier system.--Herb. Abs.

Brown, B. A.
1937. technic in pasture research. Amer. Soc. Agron. Jour. 29(6): 468-476.

While indicating the vastness of the subject the author confines his attention "to a few topics peculiar to this relatively new subject 'pasture experimentation.'" In discussing grazing versus mechanical cutting as a measure of productivity, emphasis is laid on the effect of grazing animals both on the botanical composition of the herbage and on the nutrient status of the soil, and on the limitations of cutting followed by chemical analysis, which, for example, give no indication of protein quality. The clipping of caged areas affords a reasonably accurate method of determining the production of fenced pastures varying only in one of the factors, soil type, direction of slope, fertilization or botanical composition. Among the subjects discussed are, the significance of time and rate of grazing, the expression of results by the standards of Ormsby and Eckles, choice of cutting implement, treatment of cut herbage, and methods of determining the botanical composition of swards. The number of viable seeds planted affords little information as to percentage establishment, particularly in mixtures. Seeding at different dates favours certain

species and penalizes others; clovers are generally favoured by spring and grasses by late summer and autumn seeding. Commonly used soil sampling methods are inadequate for sampling the surface soil of grassland. A new procedure is described. Little is known of the fertility requirements of different species and varietal and strain tests under different levels of fertility are advocated. Legumes should of course be favoured, but the application of nitrogenous manures three or four times a year is a useful means of suppressing volunteer species, particularly wild white clover, where potential total and seasonal yields of grasses are to be measured.

Campbell, R. S.
1940. range management research methods in the western united states. Imp. Bur. Pastures and Forage Crops, Herbage Rev. (8): 121-138.

The range research problem is to determine how the continued productivity and use of the vast native forage resource can be maintained at the highest level in harmony with economic livestock production and the conservation of other resources on the range. The organization and scope of work in the western domain, initiated by the Forest Service, has been described in Herbage Rev. (5): 1-13, 1937. The present work indicates some of the more important experimental methods employed, described under headings which include: management studies on semi-desert ranges; pasture studies on northern shortgrass plains; cattle pasture experiment in the Annual Plant Type; sheep grazing; ecological studies on high mountain summer ranges; and correlation of grazing and timber reproduction.

____
1943. progress in utilization standards for western ranges. Wash. Acad. Sci. Jour. 33(6): 161-169.

Summarizes recent advances in information needed by managers in currently judging forage utilization and relative condition of ranges in western United States. Range condition or state of productivity is related mainly to stage of plant succession. Trend of condition relates to direction of plant change. A summary of seven years' study of factors influencing cattle utilization of Bouteloua eriopoda in southern New Mexico is given. Several methods of establishing proper utilization of important forage species are compared and methods of estimating degree of forage utilization are considered.--Biol. Abs.

Dasmann, William P.
1951. some deer range survey methods. Calif. Fish and Game 37(1): 43-52, illus.

As events make necessary more intensive management of deer herds, inventories become essential to determine vegetation and soil condition trends on deer ranges. The line-point method and the line-interception

method of sampling vegetation cover are used in California where intensive survey methods appear necessary. When coupled with checks on shrub and tree form and age classes, and on forage utilization, either method will inform about present condition of deer range and indicate current trend as influenced by forage utilization. Also, either method will provide a base with which future measurements may be compared to determine periodic trend and to show ecological changes in vegetation cover. Two browse utilization check methods, the twig measurement and the visual estimate method, are used in California deer range surveys. Several suggestions regarding technique are given in the paper. A simple growth index based on average seasonal twig length is described.--W. P. Dasmann.

Davies, J. G., and Trumble, H. C.
1934. grassland research in australia: notes on the technique of pasture investigations. Imp. Bur. Plant Genet., Herbage Plants Bul. 14, pp. 23-32.

The following points are discussed, (1) the determination of botanical composition, (2) the determination of yield of herbage, (3) the determination of productivity in terms of the grazing animal and its products, and (4) the determination of chemical composition. Some excellent points are discussed in regard to carrying capacity and ocular estimation.

Davies, William.
1931. methods of pasture analysis and fodder sampling. Welsh Plant Breeding Sta., Aberystwyth, Rpt. 1, 29 pp.

Methods of pasture analysis and of hay sampling in use among research workers, more especially at Aberystwyth, are discussed. The analytical work upon which the paper is based is described under six headings, the first three dealing with the analysis of pastures [(a) the single plot of mixed herbage, (b) an acre of pasture, and (c) the pure species plot] and the last three with the analysis of cut herbage [(d) the fodder sample for air drying, (e) the fodder sample from a plot sown with a single species, and (f) the fodder sample from a plot sown with mixed grasses and clovers]. Among the main points stressed, the following are of interest. In botanical analysis of pasture plots, 10 samples should be taken at random per plot of 1/100-acre or less in order to obtain a reliable mean result for the proportion of each constituent species. All plots should be replicated five times in critical field trials and detailed ecological studies of plant communities. Instead of the usual percentage frequency method involving lifting and teasing out of turfs, it is suggested that an eye estimation should be made of the number of tillers of each species and their proportion to the whole that occur within the mark. A scale of 0-10 is used, 10 being the total marks allotted for each reading. For hay analysis, a 1 lb. green hay sample drawn after careful sampling is sufficient for a reliable result. This can be

reduced to a minimum of 6 oz. when only one or two species are present. A representative 2 lb. green sample is of sufficient bulk to give a reliable indication of the loss of moisture during air-drying. These smaller samples are taken in the first place from large "field samples" of about 10 lb. green weight. For calculation of the percentage productivity of constituent species of a hay sample, the laboratory sample is divided into 10 subsamples and a total of 10 marks is allotted to each subsample, the proportion of each species being expressed on a scale 0-10. The summated results in report of the 10 subsamples give the estimated percentage productivity of the whole sample. The point quadrat method of pasture analysis is described and it is suggested that a modification might be suitable for analysis of cut herbage.--Herb. Abs.

Davies, W., Heddle, R. G., Robinson, D. H., and others.
1933. methods of pasture analysis. Agr. Prog. [Cambridge] 10: 223-252.

Davies gives resume of history of quantitative pasture investigations and a summary of the percent tiller estimate method by which, with a 6 X 6 in. grid, the number of tillers in the turf is estimated by eye and checked from time to time by lifting the turf and counting the tillers. Heddle discusses specific frequency method, the same as Raunkiaer's. Robinson outlines percentage frequency method, in which the units are numbers of plants or tillers, counts being made on a 6 X 6 turf which is removed and examined in the laboratory. A possible defect might be that units would continually be modified in light of experience. Percent productivity method is the same, except that the units are weights. Fenton discusses percent area method by which a 10 X 10 in. grid, subdivided by brass wires into sq. in., is estimated by eye. It is said not to be applicable when vegetation is long. He also discusses the point quadrat method, for which, instead of using a frame he uses a hollow aluminum tube with clamp and butterfly nut for fastening to a walking stick. "The point quadrat method must have a strong appeal for all those who desire statistical material unaffected by the personal factor. It does eliminate the personal factor in estimation." Horne discusses the transect method using a coil of insulated aerial wire 500 ft. long marked to show each foot. For permanent work pegs are driven every 50 ft. A 6 X 6 in. grid is used, in which 6 squares are painted white (at random) in which tillers are counted. After adjusting the line the worker walks from 0 ft. until he notes a distinct change in botanical composition... "Four random samples are then obtained within this distance, the grid being laid on the north or east side of the line, ..." He also suggests estimating area rather than counting tillers. Each 100 ft. takes approximately 1½ hrs. when the species are familiar to observer. Roberts discusses percentage productivity method in which turves are taken up and green parts weighed after drying between 98°-105° C. for 24 hours and cooled in dessicator. He suggests not going above 100°. Jones and Thomas discuss estimated productivity method. A square-foot frame used, subdivided into 10 parts. Proportional weights are estimated and checked by weighing every twentieth green sample in the field.

Donald, C. M.
1946. pastures and pasture research. 117 pp., illus. Sydney: Univ. of Sydney Press.

This book is a concise and comprehensive summary of Australian pasture problems and viewpoint. Experimental results from domestic and foreign sources are drawn upon freely for illustration. Chapter I, The Role of Pastures in Land Use Planning, includes effects of pastures upon soil structure, fertility and resistance to erosion. Effects of overgrazing in semiarid regions and rotations, species and legume effects in humid and subhumid regions are discussed. Chapter II, Pasture Competition and Seeds Mixtures, includes ecology and competitive relations of pasture species for water, nutrients and light and compounding of seeds mixtures. In Chapter III, species and strains of pasture plants, plant introduction, the ecotype in relation to breeding, breeding of strains and varietal maintenance are considered. Chapter IV is concerned with pasture management and influences of grazing on performance. Season, frequency and severity of grazing, selectiveness of grazing animals and return of nutrients are related to management. In Chapter V, The Nutritive Value of Pastures, factors influencing nutritive value and the effect of animal selectivity on the diet are reviewed. The relations of seasonal factors, protein quality, energy constituents, mineral and vitamin content and nutritive defects are considered. Chapter VI is devoted to the technique of pasture experimentation. Aspects emphasized are general principles, criteria of evaluation, experimental design and determination of yield. In studying botanical composition, density, foliage cover and basal area analyses are described.

Giöbel, G., Lundblad, K., Sakshaug, B., and others.
1940. technique of grassland experimentation in scandinavia and finland. Imp. Bur. Pastures and Forage Crops Bul. 28, pp. 7-47.

The origin of the Swedish Grassland and Peat Association and an account of its experimental work are reviewed. Techniques for quantitative measurements of grass production and techniques used in stock grazing trials are described. The former involves trials by the use of control cages and plot trials under specified cutting and grazing systems, while the latter involves records of dates of manurial treatment, times of pasturing, animal production and data on grazing capacity and palatability of the sward. The methods employed in Sweden for determining the botanical composition of the sward are field methods (notably the estimation of the degree of coverage by the Hult-Sernander procedure) and laboratory methods involving sampling after cutting, separating and weighing the different species. When areas of uncultivated, but otherwise productive soils are used for grazing in Norway, study is made of the most effective methods of utilization by means of cultivation experiments. Yield is determined in fodder units on the basis of number of grazing days and the amount of milk produced by stock on different plots. The value of new strains for

different regions of Norway is determined by means of botanical analyses and yield of dry matter. The botanical composition of the grasslands of Denmark is determined by (a) P. Nielsen's Method, (b) Raunkiaer's method, and (c) botanical weight analysis. Regulations and procedures prepared by the Government Experimental Department of Plant Culture for conducting strain trials with forage plants are described, together with techniques used in designing experiments for evaluating seeding mixtures. Methods used in Finland since 1924 for evaluating the productivity of grassland include direct and indirect estimates. A direct estimate of productivity is obtained by the use of control cages generally 4 X 4 or 5 X 5 meters in size. These cages are moved to new areas within the plot following each harvest of forage. The indirect estimate of productivity is based on a determination of livestock gains or losses in weight together with products produced by the livestock while on the pasture.

Greig-Smith, P.
1957. quantitative plant ecology. 198 pp., illus. New York: Academic Press, Inc.

Practical potentialities of various methods and techniques in quantitative study of plant communities, including statistical analyses, are assessed. The book is mainly a guide to profitable means of obtaining and handling quantitative data. Successive chapters deal with problems of description of composition, structure, and classification of communities, such as: describing vegetation in qualitative terms, positioning and number of samples to be used, comparison of sets of samples, patterns of random distribution and techniques of detection and analysis of departures from random patterns, correlations between vegetation and environmental factors, and delineation and classification of communities. A final chapter discusses the contributions to the ecologic theory that can be made by the quantitative approach, including the few integrating principles of plant ecology (succession, climax, and the community as a quasi-organism). It concludes that the quantitative approach can assess relative stability in vegetation better than preexisting methods, and that the individualistic viewpoint in plant ecology is closer to reality than the organismal concept, and the continuum than the discrete association.--Biol. Abs.

Hanson, Herbert C.
1938. ecology of grassland. Bot. Rev. 4(2): 51-82.

A discussion of methods and criteria used in ecological study, especially of grassland.

______
1950. ecology of the grassland. II. Bot. Rev. 16(6): 283-360.

This review is a supplement to that which appeared in Bot. Rev. 4: 51-82, 1938. It is restricted largely to a discussion of the characteristics of the composition (floristics and structure) of plant communities and methods of measuring them. There is a bibliography of 304 citations.

Heady, Harold F.
1949. methods of determining utilization of range forage. Jour. Range Mangt. 2(2): 53-63.

Techniques of measuring range forage utilization are reviewed. Methods based upon estimates and measurements are compared and the advantages and limitations of each are discussed. Forty-five references are listed.

Humphrey, R. R.
1949. an analysis of forage utilization methods and a proposal for utilization surveys by range condition classes. Jour. Forestry 47(7): 549-554.

Forage utilization survey methods are reviewed and some of their shortcomings for field use are given. A method of making utilization surveys on a range-condition basis is proposed. Different condition classes should be grazed at different intensities. A suggested rate for grazing each of five condition classes of range is proposed. Specific recommendations are made for simplifying the recording of utilization data to obtain wider acceptance by ranchers and technicians. An ability to designate the key forage species and to determine the condition of the range is essential. Utilization on key areas is observed and recorded directly on a map of the ranch. No data are tabulated on forms.

Joint Committee of American Society of Agronomy, American Dairy Science Association, and American Society of Animal Production.
1943. preliminary report on pasture investigations technique. Jour. Dairy Sci. 26(4): 353-369.

Committees of the three Societies have proposed tentative procedures and methods of expressing pasture yields as a guide for research workers. The report is primarily designed for the humid and irrigated sections of the country. The procedure employed may vary with the type of experiment conducted, whether it be a measure of growth response to particular fertilizer treatments, a comparison of different systems of grazing management, or some other important pasture problem. In some cases merely adaptations of some of the suggestions of procedure will be necessary. Items covered are: location of plot or paddocks; soil types and composition changes; size, shape, and fencing of pasture, and number of animals; kind, sex, size, and uniformity of animals; management of pasture, and of animals; determination of

yields by calculating amount of total digestible nutrients required by grazing animals; determining composition of herbage; digestion trials; use of pilot plots; palatability determinations; cooperative demonstrations; study of pasture flora; duration of experiment; use of fertilization and soil amendments; animal parasites; insects and rodents; determination of costs; contingent or contributing data; and photography.--Biol. Abs.

Joint Committee of American Society of Agronomy, American Dairy Science Association, American Society of Animal Production, and American Society of Range Management.
1952. pasture and range research techniques. Agron. Jour. 44(1): 39-50.

This report makes current recommended procedures and methods for pasture and range research. Numerous references to the literature are given. Suggestions are given with respect to the number of pastures per treatment, number of animals per pasture, and size of pasture for grazing experiments. The selection and allotment of pastures and animals are given special consideration. Recommended procedures for determining production of a pasture as well as forage quality are discussed. The procedures for studying pasture flora, soils, and climatic factors are reviewed briefly.

Klapp, E.
1934. über methoden der grünlands-bestandesuntersuchung. [methods of analysing grassland. Third Internatl. Grassland Cong. Rpt. 1934: 193-202.

Basing statements on the results of six years' comparative observations, the author reviews the factors which are concerned in the production of accurate and correct analyses. The following methods are not advisable: (a) purely qualitative method, (b) counts or percentage estimates of individual plants or shoots, and (c) area estimations and projection surveys. Methods aiming at the determination of the percentage yield are best for accuracy and comparison of results. The following may be used: (a) regular analyses by weighing the yield after cutting, (b) mass estimations in pasture experiments and on other areas, and (c) methods based on less accurate estimations for surveys of more considerable areas, and for supplementing plant sociological study.

Lindsey, Alton A.
1956. sampling methods and community attributes in forest ecology. Forest Sci. 2(4): 287-296.

Substantial progress has been made recently in the development of improved ecological sampling techniques for analysis of forest communities. The vegetational attributes constituting the objectives

of sampling methods are redefined and their interrelationships indicated by means of a symbolic system presented in tabular form. The recent expansion of quantitative methods and concepts suggests the usefulness of symbols and formulae, particularly in the teaching of ecology. Two new summary expressions, prevalence and predominance, which integrate the role of cover with other parameters, are introduced. Two general groups of methods, detailed versus rapid survey methods, are distinguished. Detailed sampling techniques include the quadrat method involving surveyed boundaries, and the line-strip method -- which combines a linear unit and an areal strip but in which only the line is surveyed. Rapid methods include distance or spacing methods such as the random-pairs and the preferable quarter method, and the Bitterlich variable-plot-radius method. The various methods are evaluated, and a new method, involving use of instruments from one point to combine variable-radius sampling with the quadrat, is suggested.--Auth. sum.

Linehan, P. A.
1956. methods of pasture evaluation. European Grassland Conf. Sum. 1954: 110-112.

Pechanec, J. F., and Pickford, G. D.
1937. a comparison of some methods used in determining percentage utilization of range grasses. Jour. Agr. Res. 54: 753-765.

Schechtner, G.
1959. zur technik der probenahme bei grünlandversuchen. [sampling technique for grassland experiments.] Das Grünland [Bonn] 8(7): 44-46, illus.

In addition to a brief review of known herbage-sampling techniques, two instruments which have been developed at Gumpenstein, Austria are described. The first is a fodder borer used in sampling mown hay for dry-matter content and chemical analysis. The essential feature of this instrument is its spiral cut which increases the number of plants represented in the sample. The second instrument is a pair of grass-cutting shears which, to reduce effort, has the opening and closing mechanism perpendicular to the plane of cutting. The grass is cut in one strip, and since the shears give a narrow cut, the strip is long, and the sample therefore satisfies the requirement of including as many plants as possible. With skill in handling, the herbage can be cut with plants lying side by side.

Vries, D. M. de.
1937. methods used in scientific plant sociology and in agricultural, botanical grassland research. Imp. Bur. Pastures and Forage Crops, Herbage Rev. 5: 187-193.

Vries, D. M. de.
1949. übersicht über die bestandes- untersuchungsmethoden von grünland. [survey of methods of botanical analysis of grassland.] Fifth Internatl. Grassland Cong. Proc. 1949: 143-153.

Wacker, F. W.
1943. vergleichende prüfung von landwirtschaftlich brauchbaren verfahren der grünlandbestandes-untersuchung. [a comparison of methods for the investigation of green-land associations, practicable in agriculture.] Pflanzenbau [Leipzig] 19(11): 328-348; 19(12): 349-363, illus.

A number of analyses with the several methods of studying plant associations were made to find the best one for determining the composition of the green-land. It was found that the most complete list of species is obtained by the total analysis of the crop (cutting all plants in a definite area and determining the percentage (weight) of the several species). Further discussion of comparative methodology is presented.

Wagner, R. E.
1952. weight estimation and other procedures for measuring the botanical composition of pastures. Sixth Internatl. Grassland Cong. Proc. 1952: 1315-1321.

B. CLIPPED OR MOWED PLOTS

Austenson, H. M.
1958. use of a field chopper for harvesting forage plots. Agron. Jour. 50(4): 231-232, illus.

A commercial rotary forage harvester was adapted for harvesting and weighing hay and pasture plots. In comparison with the conventional method of cutting with a sickle bar mower, raking and carrying to a scale, the chopper required half as many man-hours per plot and the coefficient of variability was reduced by half. Ground surface must be smooth for effective operation.--Biol. Abs.

Beruldsen, E. T., and Morgan, A.
1937. irrigated pastures - rotational grazing. yield sampling and botanical analysis. Victoria Dept. Agr. Jour. 35: 94-103. (See JOINT ANIMAL-VEGETATION RESPONSE]

Brown, B. A., and Munsell, R. I.
1945. deterioration of clipped caged areas in permanent pastures. Amer. Soc. Agron. Jour. 37(7): 542-548.

In each of three differently fertilized, grazed permanent pastures, caged areas, clipped with grass shears for 11 years, had decidedly less grass, many more weeds, much more bare ground, and consistently smaller yields including the weeds, than nearby areas caged for only 1 year. Except for K, there were no important differences between the chemical analyses of the vegetation from the fixed and moved cages. The 10-year average difference in total yields between continuously caged, clipped areas and those caged and clipped for only one season was greatest (61 percent) on the unfertilized pasture, medium (33 percent) under LPK fertilization, and least (16 percent) where, in addition to LPK, a liberal amount of N was applied annually in April. For the differently fertilized pastures, the average grazed yields varied from 71 to 119 percent of the yields from the fixed cages and from 58 to 74 percent of the yields from the moved cages. Although the yields of the fixed cages were closer to the grazed yields than those from the moved cages, the markedly greater prevalence of weeds under continuous clipping throws much doubt on the applicability of that method as a substitute for grazing in measuring the production of pastures.--Auth. sum.

Campbell, Robert S., and Cassady, John T.
1949. determining forage weight on southern forest ranges. Jour. Range Mangt. 2(1): 30-32.

Some southern (U.S.A.) forest ranges have a pine litter of 6-10 tons per acre. They yield only a fraction of the forage produced by open

forest ranges. Forage weight is determined by a modification of the method of Pechanec and Pickford developed for western ranges. Forage is clipped and weighed in grams from a plot 3.1 ft. sq. The grams weight multiplied by 10 equals lbs./acre. Litter (pine and oak leaves), old growth (previous season's herbage), weeds, and grass are harvested and weighed separately. The method has proven satisfactory on ranges whose production varied from 10 to 5000 lbs./acre.

Cassady, John T.
1941. a method of determining range forage utilization by sheep. Jour. Forestry 39(8): 667-671, illus.

The method consists of clipping and weighing individual samples of several important forage species shortly before grazing and repeating the process soon after grazing. Each specific sample consists of several observations (weight-records) obtained from several mechanically located points on the area chosen as representative. An observation is composed of a pre-determined number of plant units (stem, leaf, twig) of the species involved.

Cowlishaw, S. J.
1951. the effect of sampling cages on the yields of herbage. Brit. Grassland Soc. Jour. 6(3): 179-182.

An experiment was conducted to examine the differences in yield under sampling cages as compared with unprotected areas. The results show that the yields of green and dry matter from under cages were significantly greater than the yields from unprotected areas. The implication of these differences is discussed in relation to measurements of herbage yields on grazing experiments.

Culley, M. J., Campbell, R. S., and Canfield, R. H.
1933. values and limitations of clipped quadrats. Ecology 14: 35-39.

There are several points of difference between clipping and actual grazing by live-stock which prevent direct and unqualified application of the results in range management: (1) in clipping, the vegetation is cut uniformly at a given height, whereas the grazing animal breaks off the stems and leaves at a convenient height, (2) the natural preferences of livestock are not simulated in clipping studies, (3) with plots as small as one meter square there is some question as to the accuracy of the results which is, of course, reduced by replication, (4) the trampling factor is not present, (5) the accumulation of litter on clipped quadrats differs from that on a grazed range.

If properly conducted, however, it may show the following relationships: (1) forage yield each year over a period of years, (2) variation in yield between species, (3) relation of yield to soil moisture,

(4) relation of tuft area or plant cover to soil moisture, (5) relation of both yield and tuft area to frequency and degree of harvesting, (6) relation of height growth, leaf length, number of flower stalks and tuft area to yield, (7) relation of nutritive and mineral values of clipped material of soil moisture and to frequency and degree of harvesting, (8) probable trends in plant succession under different degrees of cutting. Author claims the method has proven valuable in showing the proper degree of utilization.--Herb. Abs.

Davies, J. G.
1931. the experimental error of the yield from small plots of natural pasture. Austral. Council Sci. and Indus. Res., Bul. 48, 22 pp.

Three-eighths of an acre of typical "natural pasture" was divided into 760 plots, 5 X 10 links in size, herbage air dried. Eighteen different combinations of plots were made to determine the best size and shape of plot to use in sampling pastures for yield. Standard error of a unit plot (50 square links) was 34.28 percent of the mean yield of the plot, considerably higher than that of field crops. Optimal size of plot appears to be long and narrow, 5 X 90 links. In natural pastures there is a minimal size of plot to use below which the distribution of yield is nonnormal and the standard deviation is not reliable. The minimal size plot which will give a normal distribution of yield is 150 square links, 5 X 30 links. Botanical composition greatly affects yield.

Elliott, I. L., and Lynch, P. B.
1958. techniques of measuring pasture production in fertilizer trials. New Zeal. Jour. Agr. Res. 1(4): 498-521.

A description is given of a series of experiments at the Rukuhia Soil Research Station where the responses of pasture to a number of fertilizers were measured by several different techniques. The techniques are compared as follows: (1) as measures of total pasture production; (2) as measures of responses to fertilizer treatment; (3) errors of estimation attached to each technique; (4) effects of techniques on the species composition of the sward; (5) effects of techniques on the chemical status of the soil; and (6) labour and land requirements of each technique. For trials where stock production data are required in addition to pasture production data and where it is considered essential that treatments be compared under normal grazing management by stock, the "cage" technique is operated by the Extension Division is considered to be the most useful and reliable method. For small-plot trials where the primary aim is an estimation of fertilizer response by pastures, and where an accurate measure of total pasture production is not required, the "mowing and clipping returned" technique is satisfactory. Certain limitations to the "mowing and clippings returned" technique are discussed.--Auth. sum.

Glenday, A. C.
1959. mathematical analysis of growth curves replicated in time. New Zeal. Jour. Agr. Res. 2(2): 297-305.

Alternative mathematical models for the analysis of growth curves replicated in time are fitted and their efficiencies in a field growth study compared. Modifications of the models necessary for their application to data where the time replication interval is greater than the recording interval are described. The magnitude of bias in the parameters fitted because of systematic errors in the preliminary cutting of the plots, is determined. An example of the mathematical procedure is also given.--Auth. sum.

Heady, H. F.
1957. effect of cages on yield and composition in the california annual type. Jour. Range Mangt. 10(4): 175-177, illus.

Comparisons were made of the growth of annual grass vegetation in California under wire-netting cages (1.5-in. mesh) and in the open. The cages were 3.5 ft. in diameter and 2.5 ft. high. From 8 November, 1955, to 3 March, 1956, the average oven-dry weight of herbage from a caged site was 3.46 g. per sq. ft., compared with 2.33 g. on an adjacent uncaged area; the production of grass under a thin tree canopy was 2.38 g. per sq. ft. under cages and 1.88 g. on an uncaged area. These differences were both significant at the 0.01 percent level. Where the cages were in place from November to May, or March to June, forage yields under cages did not differ significantly from that of adjacent uncaged areas. It is concluded that on this type of vegetation in California, cages result in small, but significant, increases in growth during the winter season, but the differences soon disappear when temperatures rise enough to permit rapid growth. The use of cages had no detectable effect on botanical composition or soil surface conditions.--Herb. Abs.

Hebblethwaite, P., and Hughes, M.
1959. estimating the soil content of herbage collected by forage harvester. Brit. Grassland Soc. Jour. 14(3): 169-171.

A method is described for estimating the amount of contamination by soil caused when herbage is collected with a forage harvester. Hand-cut samples of herbage are used as a control. To avoid subsampling errors a relatively large sample is used. It is oven-dried and then compressed to facilitate ashing. Acid-insoluble ash ("silica") content is used as a measure of contamination. The statistical examination of the data is discussed briefly.

Jagtenberg, W. D., and Boer, T. A. de.
1957. de bruikbaarheid van graskooien voor opbrengstbepalingen. [the usefulness of grazing cages in pasture yield determinations.] Landb-Voorl. 14(12): 622-623.

The effect of cages on grass production in ungrazed pasture was investigated in the wet summers of 1952, 1953, and 1954, in nine trial plots, six of which were on clay soil, two on sandy soil, and one on peaty soil; five cuttings at intervals of 35 days were made each season. Under the cages, dry-matter content of the grass was always lower than in the open field. Dry-matter production under cages on clay soil was up to 15 percent greater than in the open field, but on the other soils no significant difference was observed. When rainy conditions prevailed, the cage-effect was smaller. A high correlation was found between the dry-matter content of the grass and increased yield (on clay soils) under the cages. On Netherlands clay soils, grazing cages were found to be unsuitable for accurate research on grass yields.--Herb. Abs.

Jagtenberg, W. D., and Boer, T. A. de.
1958. de invloed van graskooien op de grasopbrengst. [the influence of grazing cages on grass yield.] Landbouwk. Tijdschr. [The Hague] 70(12): 879-889, illus. [In Dutch with English summary.]

Full numerical data are given of experimental work on grazing cages, an account of which appeared in Landb-Voorl. 1957, 14, No. 12.--Herb. Abs.

Jones, Ll.
1958. I. technique studies on herbage assessment. Welsh Plant Breeding Sta., Aberystwyth, Rpt. 1950-1956: 111-113.

When different cocksfoot swards were defoliated simultaneously and at the same frequency, their relative herbage production varied with the mode of defoliation. The S strains were more productive than Danish when grazed by sheep, and Danish was more productive when mown. In a comparison of cutting methods, Danish yielded 1136 lb./acre when cut with hand shears and 977 lb./acre when autoscythed, while S143 yielded 1226 lb./acre when cut with hand shears and 482 lb./acre when autoscythed.--Herb. Abs.

Juvenskaja, S. I., and others.
1937. [comparison of productivity and aftermath of swards from grazed and ungrazed plots.] Soviet Bot. [Moskva] 1937(3): 99-104.

A three-year test has been carried out on four grassland plots with similar swards. The first plot was cut with scissors as soon as the sward reached the grazing stage; the second plot was first grazed and subsequently cut; the third was grazed twice and cut later, and the fourth plot was grazed only. The total of the first cut from the first plot plus the total of the first cut aftermath from the other plots is regarded as the productivity of the plot under grazing and

is compared with the total yield of the first plot ungrazed. The productivity thus recorded was much the same. No effect of these two methods on the botanical composition of the plots could be detected in this test, owing to its large variety. It is held that of all the biotic factors operating on a grassland the process of cropping (similar in its effect to cutting with scissors) is most potent, as the action of other factors involved in grazing can be modified by agronomical means.

Klingman, Dayton L., Miles, S. R., and Mott, G. O.
1943. the cage method for determining consumption and yield of pasture herbage. Amer. Soc. Agron. Jour. 35(9): 739-746.

When estimating the consumption of pasture herbage by the difference method, it was found that it is more efficient to choose the first 4 X 4 ft. area at random and its mate similar to the first, than to choose both at random. After the two 4 X 4 ft. areas are located, the one to be caged should be chosen at random. Each of 4 operators working independently greatly increased his precision by selecting the second 4 X 4 ft. area to be similar to the first. It is more efficient to place cages singly than in groups. For estimating herbage consumption and production of pastures with equal variability, the same number of cages is needed for equal precision regardless of the size of the pasture. In the pasture studied, nearly as many cages would have been needed for a 2-acre area as for the entire 12 acres. --Biol. Abs.

Linehan, P. A., Lowe, J., and Stewart, R. H.
1947. the output of pasture and its measurement. Part II. Brit. Grassland Soc. Jour. 2(3): 145-168. [See JOINT ANIMAL-VEGETATION RESPONSE]

______, ______, and ______.
1952. the output of pasture and its measurement. Part III. Brit. Grassland Soc. Jour. 7(3): 73-98. [See JOINT ANIMAL-VEGETATION RESPONSE]

Lynch, P. B.
1947. methods of measuring the production from grasslands. New Zeal. Jour. Sci. and Technol. 28(6): 385-405.

There is necessity for developing special techniques for measuring grass land production. Some of those in use are discussed and evaluated. For small plots mowing and grazing trials, clipping with clippings returned, and other approaches are discussed.

Nevens, W. B.
1945. a comparison of sampling procedures in making pasture yield determinations. Jour. Dairy Sci. 28(3): 171-185.

The direct harvest plan of sampling grass pastures is characterized by smaller standard errors and lower coefficients of variability than the difference plans. Tests of the variance of the data obtained in this investigation by 4 plans of sampling procedure show significant F values, for the direct harvest plan in a number of instances where such a finding would be expected, but no such values for the other plans. The direct harvest plan is advantageous in showing period yields and in computing yields where grazing is delayed because of a rotation plan of pasturing, or for other reasons. These advantages, together with its simplicity, make it highly suitable as the one plan of sampling where only yield determinations of grass pastures are desired. The difference plans provide a valuable check on the direct harvest plan. They are much more satisfactory than the direct harvest plan in determining yields of crops such as soybeans and sweet clover, which may either be killed or greatly retarded in growth by frequent close cutting, and are also valuable in computing period-by-period amounts of herbage consumed in grazing. Difference plan no. 2, in which open pasture yields of the previous sampling date are subtracted from the protected area samples, is proposed as an improved plan of calculating yields over difference plan no. 1, in which open pasture yields are subtracted from the protected area yields of the same date. The amount of liveweight maintained per acre is one of the valuable measurements of pasture yield.

Sprague, V. G., and Myers, W. M.
1945. a comparative study of methods for determining yields of kentucky bluegrass and white clover when grown in association. Amer. Soc. Agron. Jour. 37(5): 370-377.

Percentages of Kentucky bluegrass and white clover were determined by botanical separations and by the inclined point quadrat in trials of 15 strains of Kentucky bluegrass grown in 3 ft. X 9 ft. plots distributed at random in 4 replications and seeded uniformly with white clover. For the botanical separations, samples were clipped with grass shears before the yield strip was harvested with a lawn mower. At the first clipping date the samples averaged 20.7 percent of the yield of the harvested strip; in the 3 subsequent cuttings, the samples averaged between 12.4 and 16.2 percent. A sampling study showed that the variance within plots was low compared with the estimated true variance between plots within replications. Evidently the method of sampling provided a reliable measure of the percentage of white clover in the plots. Since the error in subsampling was low compared to variability within plots, samples one-fourth the size of the usual samples could be used. Using the inclined point quadrat, the estimated percentage of clover was lower than that found by botanical separations, the general means by the two methods being, respectively, 10.2 percent and 17.1 percent on

June 23 and 49.8 percent and 68.3 percent on October 19. Compared on the basis of strains, the greatest difference in percentage of clover between the 2 methods on June 23 was 13.0 while the least difference was 2.7. On October 19, the differences ranged from 26 to 13.4 percent. Inaccurate results evidently would be obtained by using a constant to convert the point quadrat data to a percentage by weight basis.--Auth. sum.

Wagner, R. E., Hein, M. A., Shepherd, J. B., and Ely, R. E.
1950. a comparison of cage and mower strip methods with grazing results in determining production of dairy pastures. Agron. Jour. 42(10): 487-491.

Two technics of determining production of dairy pastures were compared one with another and with results obtained from grazing over the three year period, 1946 to 1948, at Beltsville, Maryland. The data show a high correlation (r=0.94) between yields of pasture as determined by the mower strip and cage methods. Cage yields, however, were generally somewhat higher than strip yields and considerably higher than grazing results. From the standpoint of mean yields by individual pastures and mean yields of all pastures for all three years, strips gave a closer indication of grazing results than cages in these studies. The general level of the cage yields was somewhat higher relative to grazing results than that of the strip yields. However, the correlation between cage and grazing yields was greater than between strips and grazing, on a basis of individual season yields from all pastures, indicating more variability in the strip results. Much of the difference between the two methods in this respect occurred on the bluegrass pasture. In fact, while both methods were more accurate on the orchard grass than on the bluegrass pasture, there was some indication that strips estimated grazing yields of the orchard grass with slightly less variability than the cage method. On the other hand, the cage method was considerably less variable on the bluegrass pastures.--Auth. sum.

Williams, Stella S.
1951. microenvironment in relation to experimental techniques. Brit. Grassland Soc. Jour. 6(4): 207-217.

The effect of sampling cages, hurdles and fences on the enclosed microenvironment were investigated. Wind measurements were made with an Air Meter type of anemometer under all three types of protection and in the open field. Temperature and humidity measurements were taken inside both a cage and a hurdle using thermistors and the results were compared with readings from the open. Some temperature records were also taken with thermometers. The light under a cage and outside was compared. Evidence is given that wind force is substantially cut down by all three types of obstruction. Higher relative humidities and temperatures were recorded inside a hurdle than outside; these may be explained as the direct result of the wind reduction.

Evidence is also given that the microenvironment under a cage is controlled by the balance of the reduction of both wind force and solar radiation. The relative humidity is higher under a cage than in the open, but the temperature, although variable, is most frequently lower. Reference is made to the recognition of these results in experimental techniques.

Anderson, Kling L.
1942. a comparison of line transects and permanent quadrats in evaluating composition and density of pasture vegetation of the tall prairie grass type. Amer. Soc. Agron. Jour. 34(9): 805-822, illus.

Comparisons of randomized line-transects and permanent, meter-square quadrats for sampling density and species composition were made on two pastures of the tall grass prairie type in the vicinity of Manhattan, Kansas. In the quadrats, clumps of vegetation were charted in sq. cm. of area occupied at the ground surface; individual culms were given a value of 1 sq. cm. In the transects, all vegetation that came into contact with a 10-m. length of 3/32-in. steel cable stretched as near the ground level as possible was recorded. Clumps of vegetation were recorded in cm. along the wire; individual culms were given a value of 1 cm. Assuming the sampled strip to be 1 cm. in width, these culms were considered as sq. cm. of area occupied to permit direct comparisons. General agreement between the two methods was fairly close. The quadrats failed to give accurate estimates of species which were not uniformly distributed over the pasture, due, undoubtedly, to the lack of sufficient sampling. The quadrats were found likely to fail to sample widely scattered, though sometimes dense areas of a particular species, but they occasionally fell directly on such an area and gave undue emphasis to a particular species. The transect method is more rapid, and a larger number of samples may be taken in a given period. Furthermore, the samples are taken at random and are not subject to the personal bias that might be encountered in the selection of representative areas for the establishment of permanent sampling plots. In addition to providing a better comparison between pastures, the line-transect method gives a better estimate of the variability within pastures as the area is sampled by a greater number of more widely distributed points.

Bauer, Harry L.
1943. the statistical analysis of chaparral and other plant communities by means of transect samples. Ecology 24(1): 45-60.

A comparison of the transect and quadrat methods of sampling vegetation was made and, also, a comparison of three different concepts of quantitative relations, namely, (1) coverage, (2) numerical abundance and (3) frequency. The laboratory tests consisted of measurements of simulated plant communities of known composition. These "communities" consisted of colored cardboard discs assembled in various combinations. In assemblages where the discs were all of the same size, transect and quadrat sampling were about equally accurate. Transect sampling, however, requires much less time. Where the assemblages were composed of discs of various sizes (the usual situation in nature), the transects were decidedly more efficient than quadrats, where the results were expressed as coverage. The percentage of the transect line covered was a

considerably more accurate indication of the true areal coverage than was the percentage of the area covered within the quadrat samples. The advantages of coverage data, rather than numerical abundance or frequency data, are discussed. A field test conducted in a dense California chaparral indicated that, in this type of vegetation, transect sampling may save much time without loss of accuracy. Transect sampling deserves much wider use than has been made of it in the past. It is likely that, by proper adaptations, it can be used to determine most of the ecological relations for which quadrats have generally been used. --H. L. Bauer.

Buell, M. F., and Cantlon, J. E.
1950. a study of two communities of the new jersey pine barrens and a comparison of methods. Ecology 31(4): 567-586.

The forest communities in the pine barrens region of New Jersey were studied, using the quadrat and the transect methods of community analysis. The quadrat method was used to obtain density, frequency, and basal area for the tree layer. The transect method (modified from Bauer, 1935) was used to obtain cover, numerical abundance, frequency, and basal area of the tree layer, and to obtain frequency and cover in the shrub layer. A new instrument was designed for obtaining accurate crown projection for studying cover of the tree layer. The results obtained by the two methods are compared and an attempt is made to evaluate the methods.--Authors.

Canfield, R. H.
1941. application of the line interception method in sampling range vegetation. Jour. Forestry 39(4): 388-394, illus.

Estimates of density, composition and ecological structure involve only linear measurements of the intercept of plants along the line. The taking of stubble heights along the line permits an estimate of grazing use and the clipping and weighing of plants along a narrow belt transected by the line permits an estimate of forage crops. The method is efficient for both large and small areas, is economical and has a sound statistical basis.--Biol. Abs.

——— 1942. sampling ranges by the line interception method. Plant cover - composition - density - degree of forage use. South-western Forest and Range Experiment Station, Res. Rept. No. 4, pp. 28, [Processed].

The line interception method was used for sampling density and composition of range vegetation over such varying areas as small experimental plots, experimental range pastures and two large national-forest allotments. Special attention was given to forage-plant inventory and the measurement of forage use. In the first part of the paper instructions are given for sampling range vegetation. The second part deals with the compilation of results and statistical treatment of the data.

Canfield, R. H.
1944. measurement of grazing use by the line interception method. Jour. Forestry 42(3): 192-194, illus.

Three years' field experience indicates that transect lines 50-100 ft. long are adequate as units of sampling. The range is divided into blocks of a given size, and equal numbers of sample lines are distributed at random in each block. Methods of recording and summarizing the data are described and illustrated.--Biol. Abs.

Hormay, A. L.
1949. getting better records of vegetation changes with the line interception method. Jour. Range Mangt. 2(2): 67-69.

A discussion, directing attention to factors that make for efficient use of the technique.

Johnston, A.
1957. a comparison of the line interception, vertical point quadrat, and loop methods as used in measuring basal area of grassland vegetation. Canad. Jour. Plant Sci. 37(1): 34-42. [See POINT].

Parker, Kenneth W., and Savage, D. A.
1944. reliability of the line interception method in measuring vegetation on the southern great plains. Amer. Soc. Agron. Jour. 36(2): 97-110, illus.

Tests of the accuracy and reliability of the line interception method as used in sampling the vegetation on experimental pastures showed this method to be admirably suited for the accurate determination of density and floristic composition of native vegetation; but the need is stressed for careful standardization and repeated checking of field procedure. --Biol. Abs.

Whitman, Warren C., and Siggeirsson, Einar I.
1954. comparison of line interception and point contact methods in the analysis of mixed grass range vegetation. Ecology 35(4): 431-436.

Point contact methods were found to produce over-all higher density evaluations for most species and groups in mixed grass range vegetation than did the line interception method. The all-contacts variation of the point method was about equal to the line transect method in indicating the presence of species on the study area at the intensities of sampling used, but the basal-contact variation of the point system was notably poorer in this respect. When used to secure density estimates of equal accuracy for the major components of the vegetation, the point contact methods were not much more rapid than the line interception

method. Variability in species or group densities was high. The principal species and groups which made up over 70% of the vegetation on the study area showed variabilities in excess of 30% of their mean densities. Sampling to secure sampling errors not in excess of 5% of mean density at the 68% level of probability for all species and groups as used in this study, while not impossible, would be a task of considerable magnitude with any of the methods studied. In intensive studies it would be practical to sample the principal species at 5% accuracy and the most important secondary species and groups with sampling errors not to exceed 10%. For survey work in vegetation of this type and density a minimum working basis of 23 line transects, 1400 all-contacts points, or 3600 basal-contact points is suggested. This would provide for estimates of the three major components of the vegetation, needle-and-thread (*Stipa comata*), blue grama grass (*Bouteloua gracilis*), and the sedges (composite group of three *Carex* spp.) with sampling errors of 10% or less, and most of the other important species and groups with sampling errors somewhere between 10 and 20%.--Auth. Abs.

Arny, A. C., and Schmid, A. R.
1942. a study of the inclined point quadrat method of botanical analysis of pasture mixtures. Amer. Soc. Agron. Jour. 34(3): 238-247.

Data have been presented showing that percentages of certain species in pasture mixtures determined from readings from the inclined point quadrat apparatus were over- or underemphasized when compared with determinations from dry weights. A method of correcting for the overemphasis of Kentucky bluegrass alone, Kentucky bluegrass and crested wheatgrass together, and for the underemphasis of alfalfa from the readings from the point quadrat apparatus in the mixtures studied in 1941 was derived and used for that purpose. With a few exceptions, the percentages of these species as determined from the corrected readings from the point quadrat apparatus approached rather closely the percentages determined for them from dry weights.--Auth. sum.

Charpentier, C. A. G., and Saarela O.
1941. the point quadrat method of levey and its use in the investigatio of vegetation on pastures. Valtion Maatalouskoet. Julkaisu. [Finland] No. 108, pp. 31. [English summary, pp. 30-1.]

Reliable results in investigations concerning modern pasture cultivation depend to a very large extent on the determination of the composition and the changes which occur in it. For the analysis of the vegetation on meadows we have practical methods at our disposal, but these do not yield satisfactory results when the development of vegetation on pasture land is investigated. With these methods it is not possible to follow the development of the vegetation at particular spots during different periods of the grazing time and during several years in succession, nor the influence of the quality of the soil, the manuring and the grazing on the development of the plant growth of the sward.

Since 1936 the State Pasture Experimental Station at Mouhijärvi, at the suggestion of Professor K. Linkola, has been trying out the so-called point quadrat method invented by Mr. E. B. Levy of New Zealand for the investigation of vegetation on pastures. As the method showed itself in many respects considerably better suited to this purpose than the systems previously employed, an account is given in this publication of the way in which it has been applied at Mouhijärvi and of the experiences and observations so far arrived at concerning its suitability and potentialities in the investigations of the plant growth in grazed sward.

A method suitable for the above investigations should be capable of conforming with the following requirements: (1) It should be possible to undertake investigations as often as one wishes during successive summers as well as during a single summer and at practically the same spots. (2) It should be possible to avoid hay-making on the areas

under investigation. (3) The method should be relatively simple and quick. (4) The method should be as objective as possible, so that the results are not affected by a change of investigators. (5) The results should agree as closely as possible with the figures reached by weighing grass specimens.

Levy's point quadrat method fulfils the two first conditions and is moreover a quite simple and relatively quick system. Compared with several other quicker methods it is considerably more objective and more precise scientifically. When using it it is also comparatively easy to recognise the examined vegetation. A considerable disadvantage, on the other hand, is that its results do not conform sufficiently closely with those arrived at by weight analysis. In order to remedy this defect attention should be primarily directed to the development of the method.

Future investigations will reveal what possibilities of development Levy's method possesses in this respect. The advantages of the method are nevertheless so great that investigations aiming at clarifying its application are in any case justified.--Auth. sum.

Crocker, R. L., and Tiver, N. S.
1948. survey methods in grassland ecology. Brit. Grassland Soc. Jour. 3(1): 1-26.

The point quadrat method of cover analysis of pasture swards has been used for grassland surveys in the South-East of South Australia, and has proved both objective and rapid. Three to five hundred point samples per unit area (field or paddock) are usually sufficient for a reliable analysis of a pasture in survey work. Providing edaphic variability is not great, uniformity of treatment is more significant than most other factors, especially area, in determining botanical variation, and the size of paddock is not very important for the number of point samples required.

For general ecological studies on grasslands under Southern Australian conditions, the most satisfactory time to make the analyses is in the mid-late spring period. This enables the annual facies of the sward to be assessed in relation to the perennials, which in the better pastures provide the more stable framework to the associations. Many of the pastures in Southern Australia, however, are composed almost entirely of annuals. Where additional information is required, the botanical composition of the grasslands can of course be assessed by the same method at regular periods or as frequently as desired throughout the year.

Unfortunately the species in a pasture association do not all mature at the same time; that is, they do not all mature at the same stage in the edapho-climatic cycle, and most species contribute their maximum to coverage just prior to maturity. It is important to record the stage of maturity of different species when it is proposed to make further comparisons in subsequent years. The point technique, however, makes a study of the effect of variable climatic factors from season

to season on the dynamics of pasture communities a relatively simple matter, providing the foregoing observations on stage of maturity are made and the composition determined at a similar stage each year--this does not necessarily mean on the same date.

Where a species has a growth habit markedly different from the remainder of the grassland, it is better to omit it from the point analysis, and determine its frequency in some other manner. It was found necessary to do this, for example, with thistles, which in late spring reach a height beyond the possibilities of the point apparatus. Their relative abundance was determined by counting the individuals in a number of quadrats, each 2-1/2 links by 5 links in area, randomly placed over the pasture.

The chief value of grassland surveys is in the definition of pasture types and their edaphic and climatic relationships. They can also be used to assess the major successional trends resulting from various types of field husbandry, the definition of problems in pasture establishment, development or maintenance, and as a means of collating the cream of the practical experience. A number of examples have been given to indicate the type of information that can be obtained, though no attempt has been made to discuss the implications of the results in a consideration of the operation of all the ecological factors. The examples are given primarily to demonstrate the wide number of uses and value of the point quadrat technique.

Drew, William B.
1944. studies on the use of the point-quadrat method of botantical analysis of mixed pasture vegetation. Jour. Agr. Res. 69(7): 289-297.

A study was made first of the point-quadrat method as compared to the count-list method of botanical analysis of a lespedeza-grass pasture. Assuming that weight-list data furnish a reliable basis of comparison, the point-quadrat method yielded the more satisfactory results. No tendency toward underhitting of the legume or overhitting of the grass was noted. The relative efficiency of 4 different applications of the point-quadrat method was tested on the same type of vegetation. Counting all hits as the needles of the apparatus are pushed through the plants to the ground yielded more reliable results than recording the first plant hit by each of the 10 needles. Height of vegetation and morphology of species involved affected the results.--W. B. Drew.

Ellison, Lincoln.
1942. a comparison of methods of quadratting short-grass vegetation. Jour. Agr. Res. 64(10): 595-614, illus. [See OCULAR ESTIMATE].

Evans, R. A., and Love, R. M.
1957. the step-point method of sampling--a practical tool in range research. Jour. Range Mangt. 10(5): 208-212, illus.

The step-point method was investigated as a means of determining the total ground cover and percentage cover of herbaceous plants; the procedure in this case was a combination of (a) the point transect method, and (b) estimation of the percentage area in quadrats along the same transect. Equally spaced transects were laid across the test area and sampling points were equally spaced along each transect. Sampling points were established as follows: the sampler held his boot with the heel on the ground and the sole inclined at 30° to the vegetation; a sampling pin was lowered perpendicular to the sole and guided by a definite notch in the toe of the boot. The first plant struck by the pin was recorded. If no plant was struck the plant directly in front of the pin was recorded. Coverage was estimated with a square-foot frame with a cross-bar which was aligned with the notch. Using 300-500 points and 20 frame readings, this method compared favourably in accuracy with established methods, and was more rapid.--Herb. Abs.

Goodall, D. W.
1952. some considerations in the use of point quadrats for the analysis of vegetation. Austral. Jour. Sci. Res. Ser. B 5(1): [1]-41, illus.

The use of vertical pins or point quadrats in the analysis of vegetation, and the statistical treatment of results obtained with them, are discussed on the basis of data collected in different parts of Victoria. Results are expressed in terms of the proportion of the ground covered by each species ("percentage cover"), the average number of layers of foliage covering each point of ground ("cover repetition"), and the proportion of each species in the vegetation as a whole ("percentage of sward"). It is shown that pin diameter affects the results markedly, except those for percentage of sward. Percentage cover and cover repetition both tend to be over-estimated by pins. Equal distribution of points over the area under study is advocated, rather than random distribution of individual points or groups of points. Where changes in the vegetation are the main subject of interest, successive observations should be made at the same points. The use of transformations in the statistical treatment of the data is discussed. It is shown that the number of contacts of a pin with a given species can generally be fitted by a negative binomial distribution, if the number of points at which there is no contact be ignored. Subjective factors may lead to consistent differences between observers recording the same vegetation by the point-quadrat method, but these differences are small compared with those occurring with many other ecological techniques.--Auth. sum.

Goodall, D. W.
1953. point quadrat methods for the analysis of vegetation. the treatment of data for tussock grasses. Austral. Jour. Bot. 1(3): [457]-461, illus.

An improved estimate of the mean cover repetition in the centres of tussocks may be obtained by fitting a negative binomial distribution by successive approximation.--Auth. sum.

Johnston, A.
1958. note on personal error in estimates of basal area when using the vertical point method. Canad. Jour. Plant Sci. 38(3): 382-383.

_____ 1957. a comparison of the line interception, vertical point quadrat, and loop methods as used in measuring basal area of grassland vegetation. Canad. Jour. Plant Sci. 37(1): 34-42.

The methods were compared on selected, uniform areas of three range types: Festuca/Danthonia, Agropyron/Stipa and Bouteloua/Stipa. In each range type, records were taken along 10 transects, each of 100 ft. Only plant crowns were recorded; the results therefore represent basal area. Line-intercept measurements were made to the nearest 0.01 ft.; point readings, with pins of 3/32 in. diameter were taken at 1-in. intervals along each 100 ft. transect; and in the loop method, the crowns of vegetation appearing within a 0.75 in.-diameter loop which bisected the transect were recorded. The average percentage basal area of vegetation determined by the loop method was 2 to 3 times that determined by the point method which was a little higher than that by the line intercept. The loop method was the most rapid to use in the field; it detected the fewest species and gave the most variable data, especially when the dominant plants were single-stemmed species, e.g. Agropyron smithii, or grasses of the open bunch type such as Danthonia parryi, but it was a useful method for Bouteloua gracilis and grasses of a similar growth habit. The line-interception method was the most time-consuming; it detected more species than either the loop or the point and gave data which were slightly more variable than the point method. The point method gave the least variable data, and in general, seemed the most satisfactory for characterizing the vegetation of the range types studied. Sampling intensities required at 4 locations to sample the dominant species (by 3 methods) and the secondary species (by 2 methods) within ± 10% of their respective means, using basal areas, are tabulated.--Herb. Abs.

Kemp, C. D., and Kemp, Adrienne W.
1956. the analysis of point quadrat data. Austral. Jour. Bot. 4(2): [167]-174.

The type if distribution followed by point quadrat percentage-cover data has been studied. The hypergeometric type IIA distribution with constant n has been deduced from theoretical considerations and found to give a good fit to data published by Goodall in 1952. The parameters of this distribution assist the study not only of the overall percentage cover but also of the patchiness of the vegetation. The assumption of this type of distribution does not preclude the use of the angular transformation; this remains the appropriate transformation for stabilizing the variance. Theoretical considerations have been put forward in support of the policy of reducing the number of pins per frame. However, if this is done, the number of necessary locations is increased; only by practical experimentation can the optimum number of pins per frame be determined.--Auth. sum.

Levy, E. B., and Madden, E. A.
1933. the point method of pasture analysis. New Zeal. Jour Agr. 46: 267-279, illus.

Robinson, P.
1955. the estimation of ground cover by the point quadrat method. Ann. Bot. (n.s.) 19(73): 59-66.

In studying pasture composition it has been found that with certain species the numbers of individual plants per sample quadrat followed the negative binomial distribution. Others, however, where the isolation of individuals is difficult, such as grasses showing a creeping type of growth, did not appear to follow this distribution. Another method of pasture analysis is therefore required, and the paper describes an examination of a pasture in Kenya by the Point Method described by Levy and Madden. It is suggested that for pastures less uniform than those normally found in Great Britain there should be a greater distance between the points of the apparatus for it to be efficient.--Auth. sum.

Spedding, C. R. W., and Large, R. V.
1957. a point-quadrat method for the description of pasture in terms of height and density. Brit. Grassland Soc. Jour. 12(4): 229-234, illus.

This paper is a contribution to the concept of height of a dense sward. The concept takes into account the distribution of herbage density throughout the height range of a sward. The method described measures the proportion of a sward which attains a series of heights at 1-in. intervals. To do this, a point-quadrat apparatus is used. The point quadrat is mounted on one side of a tripod frame (for stability); the pins are slender, solid cylinders, graduated in inches, and have blunt ends. Herbage density at each inch level is regarded as being proportional to the number of hits obtained at that level. The apparatus is placed in the pasture according to some accepted method of random sampling. The pins are lowered to ground level and every hit by some part of a plant within each inch band is recorded. For each species

and for each 1-in. height band, the readings are converted into the number of hits per 100 points. When this series of numbers is plotted against height, a curve is obtained which shows the relationship between height and density of the sward. Mean density is calculated as the total number of hits in all height bands divided by the maximum height. The height on the curve which corresponds with the mean density is the height index. This is regarded as the effective height of a sward. The method has been used to follow the development of swards under different treatments and to provide an objective measurement of the sward in terms of height and density.--Herb. Abs.

Sprague, V. G., and Myers, W. M.
1945. a comparative study of methods for determining yields of kentucky bluegrass and white clover when grown in association. Amer. Soc. Agron. Jour. 37(5): 370-377. [See CLIPPED PLOT].

Tinney, Fred W., Aamodt, O. S., and Ahlgren, Henry L.
1937. preliminary report of a study on methods used in botanical analyses of pasture swards. Amer. Soc. Agron. Jour. 29(10): 835-840, illus.

Six methods for making botanical analyses of pastures, viz., string, vertical and inclined point quadrat, specific frequency, percentage frequency, and percentage area were tested for accuracy and practicability. On the basis of relative F values, labor, and accomplishment, the use of the specific frequency and percentage frequency methods when used with a grid is not encouraged; if the information which either provides is desired, one of the two point quadrat methods or the string method may be used instead. The two point quadrat methods show the greatest merits for a rapid and reliable means of determining the composition of a pasture and, in addition, an indication of productivity. The inclined point quadrat method covers the greater area per reading and consequently increases the accuracy, and is more easily used in tall vegetation. More experience and data are necessary to evaluate accurately the respective merits of the methods and the purposes and conditions best adapted to their use.

VanKeuren, R. W., and Ahlgren, H. L.
1957. a statistical study of several methods used in determining the botanical composition of a sward: I. a study of established pastures. Agron. Jour. 49(10): 532-536.

Several methods for determining the botanical composition of pasture swards were compared. They included the inclined point quadrat, vertical point quadrat, visual estimates of percentage composition of the standing forage and of the green harvested material, and hand-separation. The hand-separation method was used as the standard. Areas measuring 2 ft. X 2 ft. were chosen at random at 20 locations in each of 7 pastures containing various mixtures of alfalfa, smooth bromegrass, Ladino clover, Kentucky bluegrass, white clover, and medium red clover. The

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] height. The height of the [illegible] [illegible] [illegible] [illegible] [illegible] the height [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] different instruments [illegible] [illegible] [illegible] [illegible] [illegible] terms of [illegible] [illegible] [illegible].

[illegible], J. L., and [illegible], J. L.
1954. A comparative study of methods [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]. Jour. [illegible] [illegible].

[illegible] [illegible], [illegible], [illegible]
1953. Preliminary report of [illegible] [illegible] methods and instrumental analyses of [illegible] [illegible]. [illegible] [illegible] [illegible].

[illegible] [illegible].

[illegible], H. [illegible], and [illegible], W. L.
1937. A statistical study of [illegible] methods used in [illegible] [illegible] mechanical [illegible] [illegible] [illegible]. Jour. [illegible] [illegible].

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

inclined point quadrat method gave reliable and objective estimates of the botanical composition of pasture swards. The visual estimation methods for deriving percentage composition had greater variation than the point quadrat methods. Correction factors were calculated for the inclined point quadrat methods. The percentage of medium red clover was under-estimated and that of Kentucky bluegrass was over-estimated in these tests. From auth. sum.

Van Keuren, R. W., and Ahlgren, H. L.
1957. a statistical study of several methods used in determining the botanical composition of a sward: II. a study of several forage mixtures. Agron. Jour. 49(11): 581-585. [See OCULAR ESTIMATE].

Whitman, Warren C., and Siggeirsson, Einor I.
1954. comparison of line interception and point contact methods in the analysis of mixed grass range vegetation. Ecology 35(4): 431-436. [See LINE INTERCEPT].

Wilson, J. W.
1959. analysis of the spatial distribution of foliage by two-dimensional point quadrats. [with appendix by J. E. Reeve]. New Phytol.[London] 58(1): 92-101.

The quantitative method for estimating grassland cover described by Levy and Madden [Herb. Abs. 3, p. 185, 1933] is criticized and a modified method is advocated from which summated data provide an estimate of the total area of foliage per unit area of ground (leaf-area index). --Herb. Abs.

Winkworth, R. E.
1955. the use of point quadrats for the analysis of heathland. Austral. Jour. Bot. 3(1): [68]-81, illus.

A brief theoretical examination of the relationships between the orientation of leaves on a plant and the area of their projections is made and it is then shown how, for heathland species, inclined point quadrats give appreciably different and usually higher estimates of percentage cover than do vertical point quadrats. The use of inclined point quadrats for estimation of percentage contribution to the vegetation is examined and found to have no real advantage since no increase in precision is obtained with their use. Errors caused by the thickness of point quadrat pins are found to be large for the estimation of percentage cover in the microphyllous heathland vegetation. These can be minimized by the use of a cross-wire sighting tube, but an experiment shows that caution must be exercised in using this device because of the intertangling of the foliage of the various species. Estimates of percentage contribution were hardly affected by pin size. When pins were randomised independently over the test area, considerably lower variance for both percentage cover and contribution estimates were obtained compared with pins held in frames of 10.--Auth. sum.

E. OCULAR ESTIMATE

Arens, R.

1958. zur frage der anwendung der ertragsanteilschätzung bei weidebestands-untersuchungen. [the application of the weight-estimate method to the botanical analysis of pastures.] Ztschr. f. Acker- u. Pflanzenbau [Berlin] 105(1): 44-9.

The reliability of estimations was tested against actual analysis by weight of herbage (dried to 100°C.). The test was made on a 4-year-old sown pasture the herbage of which had attained a height of about 15 cm. The estimates were made on 7 plots each 2 sq. m., distributed evenly over an area of 0.6 ha. Agreement of results by estimating and weighing was remarkably good, even when inexperienced assistants estimated. Any divergencies in results were regular, e.g. Festuca pratensis and F. rubra showed consistently higher, and Poa pratensis a consistently lower, estimated weight than actual proportion by weight. Differences between estimators were also consistent.--Herb. Abs.

Beruldsen, E. T., and Morgan, A.

1934. notes on botanical analysis of irrigated pasture. Imp. Bur. Plant Genet., Herbage Plants Bul. 14: 33-43.

The "% estimation method" of botanical analysis, as here described, is synonymous with the "% productivity method." As far as a single estimation is concerned, the method possesses the advantages of (a) rapidity, and (b) requisite accuracy when a good growth of herbage is present, and the disadvantages of (a) inaccuracy when growth is poor, and (b) inaccuracy on herbage of which the component species are very intimately mixed. In watering and manurial trials, it is practicable in most cases to take a sufficient number of readings per plot and a sufficient number of replications to show that differences of 20% in the values of the major species are significant. Where total grasses or total clover are estimated, differences of less than 20% are significant. On grazing trials, particularly where grasses very similar in general appearance are preferentially grazed, the method is more accurate than observational methods. With suitable lay-out, the number of estimations per plot and the number of replications may be adjusted largely to suit practical convenience without materially affecting the accuracy of the results.--Auth. sum.

Blackman, G. E.

1932. an ecological study of closely cut turf treated with ammonium and ferrous sulphates. Ann. Appl. Biol. [London] 19: 204.

Area under observation a square 10 X 10 ft. A grid 6 X 6 in., containing nine smaller squares (2 X 2 in.) is thrown down 10 times at random on the plot and areas covered by weeds and grasses are estimated at each throw. ..."To test the accuracy of this method of random sampling, a hundred grid estimations were made on the same plot during a period of

two days. When the samples were summed in groups of 10, the resulting figures agreed within a small margin." Ammonium sulphate and ferrous ammonium sulphate reduced the weeds, including Achillea and Trifolium, and increased the grasses.

Burton, Glenn W.
1944. estimating individual forage plant yields. Amer. Soc. Agron. Jour. 36(8): 709-712.

This study is an appraisal of a yield estimate method which consists of rating the yields of spaced plants from 1 to 5 or 1 to 10 by visual examination. Several hundred spaced plants in strain tests of Dallis and Bahia grass were rated and the results were analyzed statistically. Individual A, who had had considerable experience with the estimate method, was able to duplicate yield ratings of Dallis grass on consecutive days with sufficient accuracy to make the variation associated with duplicate ratings of individual plants insignificant when compared with the other sources of variation in the strain test. This estimate method gave significantly different strain means which correlated well with the actual yield means. Three individuals differed significantly in their ability to correctly rate the yield of Bahia grass plants and to improve with training. The accuracy of each individual was significantly improved by comparing his yield estimates with actual yields before rating a group of plants.--Biol. Abs.

Costello, David F., and Klipple, Graydon E.
1939. sampling intensity in vegetation surveys made by the square-foot density method. Amer. Soc. Agron. Jour. 31(9): 800-810.

The number of 100 square-foot plots required for a reliable statistical sample in range surveys varies between portions of a vegetation type and between different types. The number of plots necessary to sample a type bears little relationship to area of the type. Sampling a given area by means of a composite sample requires fewer plots than sampling the area on the basis of range condition classes. Sampling intensity is influenced by seasonal and yearly fluctuations in floristic composition. Either preliminary surveys or samples taken periodically from survey data provide a basis for determining the intensity of sampling required in different vegetation types.--D. F. Costello.

Davies, W.
1934. pasture sampling, with particular reference to methods used in great britain for determining the botanical composition of the grassland. Third Grassland Conf. Rep. [Zurich] 214-5.

The technique of pasture sampling for botanical composition is discussed. Methods of sampling fall into three main groups, namely: (a) frequency, (b) productivity and (c) percentage area covered.

The estimation methods are outlined in relation to percentage frequency and percentage productivity. The basis of these methods is that (a) an

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[illegible]

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[illegible]

[illegible]

[illegible]

adequate number of samples be drawn from properly replicated plots, and (b) estimates of frequency and productivity are made on each sample in place of detailed counts or weights respectively of separated species.

Ellison, Lincoln.
1942. a comparison of methods of quadratting short-grass vegetation. Jour. Agr. Res. 64(10): 595-614, illus.

Three methods of quadratting Bouteloua gracilis and Buchloe dactyloides vegetation--the pantograph-chart, density-list, and point-analysis methods-- were tested on 3 typical short grass quadrats of low, intermediate, and high density. Five trained observers used each method four times on each quadrat, except that the point method was used six times. On an average, the methods reflected similarly the marked differences between quadrats, although with differing absolute values. Grass areas by the chart method tended to be 50% greater than by the other methods. Areas by the list and point methods were similar. The chart method proved generally least consistent and most time-consuming of the three: its net efficiency varied from 1/2 to < 1/50 of that of the other methods. The list method tended to give the most consistent results: its net efficiency was much higher than that of the other methods, except that the net efficiency of the point method was the greater on the high-density quadrat. Consistent differences between observers were most evident on the quadrat with grass of highest density and most matted habit. Interactions were demonstrated between observers and methods. Inconsistencies, sometimes large, appeared within the work of a given observer. For estimating area of short-grass vegetation on permanent quadrats, the density-list method, carefully standardized, should be applied; the point-analysis method may be used for training and standardizing observers in the list method; the chart method should be reserved for those studies in which the greatest need is a detailed graphic record of the vegetation.--Lincoln Ellison.

Evans, R. A., and Love, R. M.
1957. the step-point method of sampling -- a practical tool in range research. Jour. Range Mangt. 10(5): 208-212, illus. [See POINT].

Goebel, Carl J., De Bano, Leonard, and Lloyd, Russell D.
1958. a new method of determining forage cover and production on desert shrub vegetation. Jour. Range Mangt. 11(5): 244-246, illus.

An improved method for estimating forage cover and production, using a subdivided 25-sq.-ft. quadrat frame, was tested on two pure vegetation types, shadscale (Atriplex confertifolia) and winterfat (Eurotia lanata) in N.W. Utah. A significant correlation was found between plant cover and current forage production, but the accuracy in estimating plant

density was dependent on inherent growth characteristics. Results for shadscale, which has a regular plant outline, were more consistent than for the irregularly defined winterfat.--Herb. Abs.

Hall, Thomas D., and Murray, S. M.
1935. the botanical analysis of intensively grazed pastures. So. African Jour. Sci. 32: 189-196, illus.

The results of a comparison of the percentage area method with a modification of the percentage productivity method made on the same areas on intensively grazed pastures under various fertiliser treatments are recorded. Data obtained at three centers, on two veld and one sown pasture experiments, were consistent, and showed that the modified productivity method gave more reliable results for grazing or carrying capacity than the percentage area method. The disadvantages of the suggested new method are outlined. A suggestion as to its possible utilisation is given, whereby yield data and rapidly made estimations might be combined to give accurate botanical analyses.--Auth. sum.

Hanson, W. D., and Hunt, O. J.
1957. a statistical technique for the evaluation of visual estimates involving components of forage mixtures. Agron. Abs. 49: 70.

Larin, I. V., Sosnovskaja, N. N., and Sljapnikova, N. D.
1933. a simplified method for determining proportion by weight of species in the swards of meadows and pastures. Sovet. Bot. [Moskva], 3-4: 267-70.

A sample of 100 grams is divided into 5-10 approximately equal sub-samples, each of which is roughly divided further into two (grasses and others) or three (grasses, sedges and others) groups; their relation to the sub-sample is eye-estimated in percentage or marks. The groups are then classified into constituent species and the percentage contribution of each species within its group is eye-estimated. The accuracy of this method was compared with that of the common method of percentage estimation by weight by analysing six samples, 4 of 35 species and 2 of 40 species. It was found that either method gave the same practical and fodder estimation of these samples. The total working hours required for estimating six samples by the common and simplified methods are calculated as 75 hours and 13 hours respectively.--Herb. Abs.

Malmstem, H. E.
1930. combination of list and chart quadrat methods for grazing studies. Ecology 11: 749-751.

After the quadrat has been subdivided into units, the density of the vegetation on each unit is estimated ocularly to the nearest 10/100, or when necessary to the nearest 5/100; the plant species are recorded in order of abundance and according to percentage of area occupied by

density not dependent on different growth characteristics, [illegible] and [illegible], which have a [illegible] plant [illegible], were [illegible] than are the [illegible] [illegible] [illegible].

Hill, [illegible], and [illegible], A. H.
1956. The statistical analysis of [illegible] grazing research. [illegible] [illegible]

[illegible] of a comparison of the percentage [illegible] with [illegible] of the percentage productivity method [illegible] [illegible] [illegible] under [illegible] [illegible]. [illegible] of three [illegible], [illegible] [illegible] [illegible] [illegible] productivity method [illegible] more reliable results [illegible] [illegible] than the [illegible]. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] yield [illegible] [illegible] [illegible] should be [illegible] to give [illegible] [illegible].

[illegible], [illegible], and [illegible]
1955. A statistical [illegible] for the evaluation of [illegible] [illegible] [illegible] of [illegible] [illegible]

[illegible], [illegible], and [illegible]
1956. A modified method for determining [illegible] [illegible] in the [illegible] of [illegible] [illegible]

A [illegible] [illegible] [illegible] [illegible] [illegible] [illegible], each of which is [illegible].

[illegible], [illegible]
1951. [illegible] of [illegible] and [illegible] [illegible] [illegible] for [illegible] [illegible]

After the [illegible] has been [illegible] [illegible], the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] in order of [illegible] and according to [illegible] [illegible] [illegible]

each; and the boundaries of important turf forming plants are carefully charted.

The advantages over the list or chart methods are: reduction in time required for making the record; and presentation of data in a form permitting ready computation of range improvement or deterioration in terms of forage acre factors or carrying capacity. With training and careful work, the error due to ocular estimating should not exceed 10 percent.

Murray, S. M., and Glover, P.
1935. some practical points regarding the detailed botanical analysis of grass-veld or other pastures by the list quadrat method. Jour. Ecol. 23: 536-539, illus.

Nissen, Ø.
1949. the use of visual estimates in place of separation analysis in experiments with hay crops. Norges Landbrukshøiskoles. Meld. 29: 225-256.

Paatela, Juhani, and Laine, Lalli.
1953. heinänurimien botaanisen koostumuksen määrittämisestä silmävar-asisesti. (on visual estimation in determination of the botanical composition of tame-hayfields.) Acta Agr. Fenn. [Helsinki] 80(2): 1-24.

In comparison with weight analysis, visual estimation generally gave a fairly accurate picture of the botanical composition of the investigated tame-hayfields at three different stages. The botanical composition of a tame-hayfield may show considerable variation even during a short time. Thus with the determination of the botanical composition of tame-hay, estimations should be made immediately before harvesting. With regard to the 4 persons conducting this investigation, subjectivity was of slight importance at the determination of the estimations of abundance. Observations as to the frequency of species showed distinct differences based upon observer. As the greatest differences, however, were found with the lowest proportion (0.1%), they could not have any remarkable influence on the average abundance of species. Thus, division of abundance into small groups (0.1, 0.5, 1.0, 2.5, 5, 10.... 95, 100%) seems justified.--From auth. sum.

Pechanec, Joseph F., and Pickford, G. D.
1937. a weight estimate method for the determination of range or pasture production. Amer. Soc. Agron. Jour. 29: 894-904.

Reid, Elbert H., and Pickford, G. D.
1941. a comparison of the ocular-estimate-by-plot and the stubble-height methods of determining percentage utilization of range grasses. Jour. Forestry 39(11): 935-941.

Reid, Elbert H., and Pickford, G. D.
1944. an appraisal of range survey methods. Jour. Forestry 42(7): 471-479, illus.

A comparison was made of (1) single ocular estimates of the average density and composition of vegetation on each forage subtype (reconnaissance method) and (2) estimates of the density of each species on regularly-spaced plots 100 square feet in area, numbering 20-36 per square mile (square-foot-density method). Five men used each method twice on the same 27-square-mile area, once with (A) type-boundary mapping from parallel survey lines 1/2 mile apart, and once with (B) mapping of types directly upon aerial photographs in the field. Where aerial photographs and base maps are already available, combination 1B is recommended. In unphotographed areas, combination 1A is usually cheaper, considering the cost of photographing, and is nearly as accurate. Method two gave satisfactory results in combination with B, but was not sufficiently accurate when used with A.

Smith, Arthur D.
1944. a study of reliability of range vegetation estimates. Ecology 25(4): 441-448.

A study was made of reliability and variability of estimates of vegetation by range reconnaissance methodology. Eight men, all experienced, estimated over a 7-day period on three vegetation types. On three days, plots previously estimated were reworked to determine variability and effect of training. Analysis of variance showed highly significant differences among men and also between days. Further, training failed to overcome interman variation. After training, estimates still varied from 71.24 to 139.81 percent of the group average. Clipped forage yield from these plots, used as a production standard, showed great variation in yield per estimated square foot of density both within and between species, e.g., grams yield per square foot was 35 for _Agropyron smithii_ and 369 for _Atriplex confertifolia_. These studies do not show density estimates to be a highly reliable measure of range value. The studies support a current tendency to rely less upon density estimation in determining grazing capacity of ranges, and more upon comparison with ranges of known productivity, and upon a general ecological analysis of soil and plants followed by percentage adjustments in current stocking rates.--L. A. Stoddart.

Steinberg, C., and Dassogno, Mireille.
1957. studio comparativo su alcuni metodi di rilevamento botanico per cotiche polifite. [a comparative study on some methods of botanical survey for mixed-species swards.] (English summary.) Ann. della Sper. Agr. [Rome] 11(3): 867-883.

Comparison was made of 6 methods of botanical survey applied to 10 mixed-species swards. It was found that visual estimation of coverage corresponded sufficiently well with survey by weight; this would justify using the former method in cases which do not require a high degree of

precision. The greatest number of species was found with the coverage method, followed by the weight method on an average sample. The frequency methods indicated the most important species with a satisfactory degree of accuracy.--From auth. sum.

Stewart, George, and Hutchings, S. S.
1936. the point-observation-plot (square-foot density) method of vegetation survey. Amer. Soc. Agron. Jour. 28(9): 714-722, illus.

The point-observation-plot method is much more accurate, easier to learn and to apply, and provides much greater consistency in the forage-volume estimates made by individual estimators than does either the chart quadrat or the large-estimate plot hitherto used for this purpose. The method is so distinctly timesaving as to make possible 10- or 20-fold replication; its system of randomising plot locations at mechanical intervals obviates "selecting" plots, the ordinary procedure in former vegetation studies. The plots are circular and of 100 square feet area. One or more series of plots in a line or in a gridiron arrangement are used to supply representative samples so highly useful for forage inventories, comparative surveys, permanent study plots and erosion surveys. The method has been widely tried and found suitable for providing quantitative data in range, agronomic, and ecological investigations.--Biol. Abs.

Van Keuren, R. W., and Ahlgren, H. L.
1957. a statistical study of several methods used in determining the botanical composition of a sward: I. a study of established pastures. Agron. Jour. 49(10): 532-536. [See POINT].

_______, and _______.
1957. a statistical study of several methods used in determining the botanical composition of a sward: II. a study of several forage mixtures. Agron. Jour. 49(11): 581-585.

A further study was made of several methods used in determining the botanical composition of a sward. Additional evidence was presented that the inclined point quadrat method and the visual estimates of the standing forage provided satisfactory measures of the percentage composition of the swards studied when compared with hand-separation. The inclined point quadrat method, however, required the use of factors to correct for under-estimation of alfalfa and medium red clover, and over-estimation of Kentucky bluegrass. The correction factor based on yield per hit gave more satisfactory results than did the factor based on the regression coefficient. The use of the regression equations to provide estimates of yield of forage by the inclined point quadrat method did not give satisfactory results, although the estimates obtained for alfalfa, medium red clover, and Kentucky bluegrass were close enough to the actual yield to indicate that the procedure may have merit.--Auth. sum.

West, Oliver.
1937. an investigation of the methods of botanical analysis of pasture. So. African Jour. Sci. 33: 501-559, illus.

Raunkiaer's law of the distribution of frequencies, the "Minimal Area" and "Constant Species" concepts are reviewed and the applicability of the methods to the analysis of grass veld in So. Africa investigated. Adaptations to meet local conditions are suggested and a new method, the "Percentage area transect method," is described. Investigation of the relation between size and number of quadrats in the percentage area method showed that the use of a comparatively small quadrat greatly reduces the amount of work necessary for accuracy. The 25 sq. dm. quadrat proved the most suitable size for use in the frankewald purple veld. In the case of the rare species in the veld, a random distribution was obtained for all quadrat sizes from 1 sq. dm. upwards; the distribution of the abundant bunchy species was not random for quadrat sizes less than 25 sq. dm., but was random when the quadrat was 25 sq. dm. or larger.--Biol. Abs.

———— 1938. the significance of percentage area determinations yielded by the percentage area or density list method of pasture analysis. Jour. Ecol. [London] 26(1): 210-217.

The percentage area method is discussed. The difficulty of using estimated percentage area results for the detection of change in pasture or grassland is pointed out. Although a strong correlation exists between the estimations made by different observers on the same quadrat, each observer estimates differently and the results of several observers cannot be compared until reduced to the same scale. It is proposed that the measurements of area covered made by means of pantograph be used as a constant scale, that all observers correlate their estimations with pantograph measurements at regular intervals and that they reduce all estimated percentage area results to the pantograph scale. In deciding on the significance of change shown in results obtained by different observers at different times, it is necessary to reduce all observations to the same scale, to compute the standard deviation of the difference of the means, and to compare the difference with its standard deviation, or with the derived value, the probable error.--Auth. sum.

F. RANKING OR RATING

Dix, R. L.
1959. the influence of grazing on the thin-soil prairies of wisconsin. Ecology 40(1): 36-49.

A study, using paired plots, was made of the effect of grazing on the vegetation of the thin-soil prairies of So. Wisconsin. The paired plots were selected for similarity to each other in all respects, except that one was subject to grazing and the other was not. The frequency method was used to sample the plant stands. A formula was evolved to indicate in terms of numbers on scales of 1 to 10 and -1 to -10, the behaviour of given species under grazing, based on their comparative densities on the paired plots. Grazing susceptibility numbers are given for 78 species. These grazing susceptibility numbers were used to evaluate the status of plant communities in regard to their behaviour under grazing. The advantages of using grazing susceptibility numbers as an index of range condition is discussed.--Herb. Abs.

Kapur, M. N.
1957. some investigations on the problem of ranking of varieties. (Abstract.) Indian Council Agr. Res. Statis. Newslet. 7(2): 16.

McIntyre, G. A.
1952. a method for unbiased selective sampling, using ranked sets. Austral. Jour. Agr. Res. 3(4): [385]-390, illus.

A new method of sampling is described. Take the largest in the first of n sets, each of n random items, the second largest in the second set, and so on to the smallest in the nth set. The sample of n items selected in this way is an unbiased sample of the population. For typical unimodal distributions the mean of such a sample is slightly less than $\frac{(n+1)}{2}$ times more efficient than the mean of n items taken at random. The application of the ranked sample method to pasture measurement is discussed.--Auth. sum.

________, and Williams, R. F.
1949. improving the accuracy of growth indices by the use of ratings. Austral. Jour. Sci. Res. Ser. B. 2(4): 319-345, illus.

A statistical procedure is developed whereby the precision of estimation of growth increments and various growth indices is greatly increased, especially where the variability of the plant material is great. The procedure takes account of the fact that the difference between the mean weights of two successive harvests includes the

difference between the sample means at the time of the first harvest. The importance of this factor is reduced by the use of ratings of both samples taken at the time of the first harvest. Weight comparisons are made by reference to the mean rating at this time or, where a succession of harvests is involved, to a suitable estimate of this mean rating. The procedure is applied to a study on growth of tomatoes on a range of soil treatments and using simple chains of leaf area ratings. It is exemplified in detail from the control series of that experiment. The data are examined critically to see whether they satisfy the assumption inherent in the development of the theory. It is found that the variables of the bivariate distributions are highly correlated, with no evidence of a departure from a linear trend. Under these conditions, bias introduced from small departures from normality in the marginal distributions will be negligible. Estimates of total weight, leaf weight, and leaf area based on maximum likelihood estimates of mean rating are more precise than are those based on mean rating at first harvest. Gains in precision in estimates of relative growth rate and net assimilation rates are quite substantial, but there is little advantage in the use of maximum likelihood estimates in place of mean rating at first harvest for this purpose. For estimates of weight, leaf area, and growth indices, the gain in information using ratings is as great for the absolute as it is for the logarithmic data. General considerations relevant to the application of the procedure are discussed, and its merits and limitations are indicated.--Auth. sum.

Michelson, L. F., and others.
1958. the use of the "weighted-rankit" method in variety trials. Amer. Soc. Hort. Sci. Proc. 71: 334-338.

The Weighted-Rankit method allows for the numerical classification of strain and variety descriptions. Each trait is weighted according to its relative importance and integrated with other weighted characteristics. The data are subjected to variance analysis, which then permits a final quantitative comparison among all the items within the test.--Herb. Abs.

Morris, M. S.
1943. a method of rating forage plants for use in range surveys. (Abstract.) Mont. Acad. Sci. Proc. (1942/1943) 3/4: 23-24. [Processed.]

Torrie, J. H.
1957. evaluation of general and specific combining ability in perennial ryegrass (lolium perenne l.). New Zeal. Jour. Sci. and Technol. Ser. A 38(10): 1025-1035.

Specific combining ability estimates calculated from visual yield scores at different seasons were highly correlated with each other and with those for spring forage yield. The correlation between

autumn and winter visual yield scores was significantly greater than either autumn or winter with spring scores. A highly significant correlation was obtained between visual yield estimates and green forage yield.--Herb. Abs.

Vestal, A. G.
1943. unequal scales for rating species in communities. Amer. Jour. Bot. 30(4): 305-310.

After a brief review of published scales having unequal divisions, a progression to serve as a basis for new scales is described. In a total range of 100 units, the first of 10 intervals is 2.5, the last is 20.9. Two of four cognate scales using these intervals have larger divisions at the top (they are called V scales); the others have smaller divisions above (A scales); both 10-parted and 5-parted forms of these are given. In an application to frequency percentages for occurrence in plots of leading forest-tree species, A 10, A 5, and equal 5-class scales are compared. Another example uses the V 5 scale to help distinguish dominant and subdominant groups of species. Classes in this scale are 62-100, 36-61, 18-35, 7-17, 0-6.--Biol. Abs.

Anscombe, F. J.
1949. the statistical analysis of insect counts based on the negative binomial distribution. Biometrics 5(2): 165-173.

This note gives a summary of the results of a mathematical investigation into sampling theory of the negative binomial distribution. Insect counts in the field (and other population counts) are often fitted fairly well by a negative binomial distribution description by the mean m and the exponent k. Methods for estimating k from a single large sample and from several samples are illustrated by a numerical example (counts of eggs of Aphis fabae on hedgerow shoots).

Drew, William B.
1944. studies on the use of the point-quadrat method of botanical analysis of mixed pasture vegetation. Jour. Agr. Res. 69(7): 289-297. [See POINT]

Hanson, Herbert C., and Love, Dudley.
1930. comparison of methods of quadratting. Ecology 11: 734-748, illus.

A study of pantograph-chart, count-list, density-list, area-list (basal area), and weight-list methods of studying vegetative changes. Results obtained by each method are different. To determine proportion of each species temporary quadrats and weight-list method is best but this method not practical for permanent quadrats. To determine changes from year to year combination of pantograph-chart and count-list methods are most desirable for single stalked or even-sized clump species. For mixture combination of pantograph-chart and area-list methods are most desirable. Area-list and count-list methods appear more accurate and require less time than pantograph-chart method in mixed prairie or irrigated pastures.

Heady, Harold F.
1958. vegetational changes in the california annual type. Ecology 39(2): 402-416.

Vegetational changes were studied on three sites located on the Hopland Field Station in Mendocino County, California, during five successive growing seasons, 1951 to 1956. The numbers of plants by species on 2400 quadrats of 1 sq. in. in size constitute the data. The seasonal growth pattern proceeds from germination, usually in November, through a short period of moderate growth, then a longer winter period when growth is slow and finally ends with about a month of fast growth in April and May. Average number of plants per sq. in. varied between 3.3 and 35.0 with different situations. All species decreased in numbers per unit of area from December to June, but

Bromus mollis, B. rigidus, and Erodium botrys decreased less than the others and, thus increased in percentage species composition. The numbers of plants per unit of area varied greatly between years as also did the various species. For example, 1953 was a year when grasses clearly dominated the vegetation. E. botrys constituted a larger portion of the vegetation in 1955 than in other years. Changes in the annual-type vegetation due to such items as grazing, seeding, fertilization, and fire are reviewed and the influence of mulch on percentage botanical composition is illustrated. The results are discussed as illustrations of seasonal, annual and successional changes in annual-type vegetation.--Biol. Abs.

Langer, R. H. M.
1958. changes in the tiller population of grass swards. Nature [London] 182(4652): 1817-1818.

From a study of the number of living tillers/sq. ft. in S215 Festuca pratensis and S48 Phleum pratense during March/August under two treatments: (i) cutting for hay and aftermath; and (ii) cutting every four weeks beginning in early April, there was evidence that both species maintained a greater population of tillers under (ii). Under both treatments tiller numbers tended to be high early in the year, but declined after mid-April. This seasonal variation in tiller numbers was accompanied by changes in the proportion of new and dead tillers. In both species, cuts for hay after ears had emerged resulted in heavy mortality among tillers, but new tiller growth was rapid and was roughly proportional to losses. Similar changes occurred under frequent cutting. Thus, the composition of the tiller population of swards in August differed from that earlier in the year. The significance of this in regard to dry-matter yields is recorded. The decline in production during summer, attributed to changes in the tiller population, is discussed in the light of selection.--Herb. Abs.

Manner, R.
1957. några synpunkter på undersökningsmetodiken i fråga om gräsmattor. [on the methods for investigating lawns.] Medd. 14 Gullåk. Växtförädl Anst. 1957, 29-33. [English summary.]

As an index of lawn sward density, the Gullåker Plant Breeding Institute has, since 1955, used the number of shoots per sq. m. The number of shoots in four 10 X 10 cm. quadrats, sited at random on a given plot, is counted. In a series of observations made in 1955, the number of shoots per sq. m. for 5 selections of Agrostis stolonifera ranged from 4,000 to 10,000, for 3 of A. tenuis from 15,000 to 19,000 and for one of A. canina, 45,000. For Cynosurus cristatus the number was 7,400, for Festuca rubra 22,200, and for F. ovina 50,000. For 5 selections of Poa pratensis it ranged from 5,000 to 10,000, for two of P. palustris it was 25,000 and 14,000 and for both P. nemoralis and P. compressa was 20,000. The relation between shoot density and

degree of vegetative cover is discussed. It appeared that a summer shoot density of 5,000-6,000 per sq. m. in A. stolonifera and P. pratensis corresponded to a cover of about 50 percent and also with a shoot density of 8,000-10,000 in C. cristatus and 20,000 in P. palustris; P. nemoralis and P. compressa. A shoot density of 20,000 per sq. m. in A. tenuis corresponded to a 90 percent cover and to shoot densities of 25,000 in F. rubra and about 50,000 in A. canina and F. ovina.--Herb. Abs.

Shimada, Y.
1958. [statistical studies on the design of a yield survey and field experiments in natural grassland. pt. 2. estimation of number of bracken plants, pteridium aquilinum (l.) kuhn., in miscanthus grassland.] Tohoku Univ. Sci. Rpts. Res. Insts. Ser. D 9(2): 132-135, illus.

The object was to determine the most efficient size and shape of sampling unit and sample size for estimating the number of bracken plants in Miscanthus grassland. The layout of the plots, which were 1 X 1 to 64 X 8 sq. m., and the manner of charting results were similar to those used for estimating the productivity of Miscanthus. The distribution of plants in the sq. m. plot followed neither the Poisson nor the Polya-Eggenberger distribution; but in plots larger than 2 X 2 sq. m. there was good agreement with the negative binomial distribution. The coefficient of variation decreased slightly with increase in size of sampling unit. A large sample was required for a reliable estimate of the bracken population.--Herb. Abs.

Pearsall, W. H.
1924. the statistical analysis of vegetation. Jour. Ecol. [London] 12: 135.

H. DISTANCE MEASURE

Bauersachs, Ewald.
1942. bestandesmassenaufnahme nach dem mittelstammverfahren des zweitkleinsten stammabstandes. Forstwiss. Centbl. [Berlin] 64(8): 182-186.

At fixed intervals on parallel strips the nearest tree is calipered and its distance from the second-closest tree to it is measured. (This is said to give more accurate results than the distance from the closest tree, in irregularly spaced stands.) The average distance, computed from about 50 measurements, gives a basis for estimating number of trees in the stand when the area is known, and average tree volume, computed from 50-100 caliper and height measurements, multiplied by number of trees, gives a close estimate of total volume of the stand.

Blackith, R. E.
1958. nearest-neighbor distance measurements for the estimation of animal populations. Ecology 39(1): 147-150.

Two published expressions linking density of organisms distributed at random in the field and comparing average distances between nearest neighbors. One is shown to give densities some four times higher than other. Practical trials of these formulae using populations of British and French grasshoppers, estimated by capture-recapture methods, favor one expression, but empirical tests with random points favor other. Nonrandom dispersal of organisms seems to introduce errors which are much less than discrepancy between population estimates as given by the two expressions.--Biol. Abs.

Catana, A. J., Jr.
1955. the wandering quadrant. a new ecological sampling method utilizing interspace measurement. Ecol. Soc. Amer. Bul. 36: 88.

Clark, Philip J., and Evans, Francis C.
1954. distance to nearest neighbor as a measure of spatial relationships in populations. Ecology 35(4): [445]-453.

Degree to which 2-dimensional distribution of individuals in a population of known density departs from random expectation can be ascertained from ratio $R = \frac{\bar{r}_A}{\bar{r}_E}$, where $\bar{r}_A$ is observed mean distance between nearest neighbors and $\bar{r}_E$ is mean distance expected if distribution were random. This ratio ranges in value from 0 for a distribution with maximum aggregation, through 1.0 for a random distribution, to

2.1491 for a distribution which is as evenly and widely spaced as possible. Methods are given for calculation of $\bar{r}_E$, its standard deviation, significance of departure from random expectation, and significance of difference between values of R from 2 or more populations. Sensitivity of measure is demonstrated by applications to synthetic and actual distributions of various patterns. Problems which arise in its use are discussed briefly and an extension of method to utilize additional spatial relationships is described. An appendix to paper gives derivation of formulas used in development of measure.--Biol. Abs.

Cottam, Grant, Curtis, J. T., and Catana, Anthony J., Jr.
1957. some sampling characteristics of a series of aggregated populations. Ecology 38(4): 610-622., illus.

Aggregation of populations is defined in terms of three interrelated variables and three indices for measuring aggregation, using distance methods, are discussed.--Herb. Abs.

_______, _______, and Hale, B. Wilde.
1953. some sampling characteristics of a population of randomly dispersed individuals. Ecology 34(4): 741-757.

An artificial population was sampled by both area methods and distance methods using exclusion angles. The population consisted of a map containing 1000 individuals located by means of rectangular coordinates taken from a random numbers table. Data on frequency, relative (percent) density, and area density were obtained. All methods indicated that random populations give highly variable results and that larger than usual samples are needed to measure the frequency and density of the species on such populations. The applications of the results to the measurement of plant communities is discussed.--Grant Cottam.

Dice, Lee R.
1952. measure of the spacing between individuals within a population. Mich. Univ. Lab. Vert. Biol. Contrib. 55, 23 pp., illus.

For measuring the spacing between the individuals in any given population which is distributed over a single plane the following method is proposed: (1) A certain number of individuals in the population are taken at random as points of origin for the measurements. (2) From each such point of origin the distance is measured in each surrounding sextant to the nearest other individual in the same population. (3) The square roots of these measurements of spacing are treated statistically to derive means, variances, and other statistics. The frequency curve of the the square roots of the measurements of the spacing between individuals taken according to the above described

method, approaches normality when the distribution of the population is random. When the individuals are clumped, the curve is skewed toward the left. When the distribution is more even than random, the curve is skewed toward the right. The significance of any irregularity of distribution may be evaluated by the g_1 and g_2 statistics. These statistics, moreover, give a measure of the degree of departure of any distribution from randomness. The relation between mean population density per unit area (P) and the mean spacing between the individuals (S) measured by sextants should be given by the formulas:

$$P = \frac{1.155}{S}, \quad S = \sqrt{\frac{1.155}{P}} .$$

These formulas seem to apply with fair precision when the distribution of individuals in a population is approximately random or is more even than random but they give erroneous values when the individuals occur in aggregations. The square roots of the measurements of spacing between the individuals of one species, taken at random as points of origin, to the nearest individuals of another species in each surrounding sextant should approach a normal frequency curve when there is no association between the two species. The curve is expected to be skewed to the left when there is association between members of the two species, or to the right when there is repulsion between them. The significance of any tendency toward association or repulsion can then be measured by the g_1 statistic. The frequency curves of the square roots of the measurements of the spacing between two species, each of which is clumped in distribution, however, exhibit negative kurtosis. The measurement of spacing between individuals should be of general usefulness for describing the structure of populations and communities in quantative terms. Its particular merit is that the measurements obtained are not affected by sample size.--Auth. sum.

Hopkins, Brian.

1954. a new method for determining the type of distribution of plant individuals. Ann. Bot. [London] 18(70): 213-227, illus.

The principle of the method is that if _I_ is the distance from an individual chosen at random to its nearest individual, and _P_ is the distance from a point chosen at random to its nearest individual, then _A_ the coefficient of aggregation, (defined as $\Sigma(\underline{P}^2)/\Sigma(\underline{I}^2)$ where the number of observations of _P_ and _I_ are equal) equals unity if the individuals are distributed independently and at random. If the individuals are aggregated, _A_ is greater than unity and vice versa for individuals regularly distributed. The results given by this method compare favorably with those given by the current quadrat methods when tested on synthetic and natural populations. The method is quicker than the quadrat methods and is especially useful for analyzing the distribution of trees. A mathematical proof of the methods used for determining the significance of observed deviations of _A_ from unity are given in the appendix.--Brian Hopkins.

Moore, P. G.
1954. spacing in plant populations. Ecology 35(2): 222-227.

The usual methods of statistical examination of plant populations have been concerned with the idea of sampling by quadrats. In this paper attention is focussed on the use of the spacing in plant populations as a basis for the examination of problems concerning (1) the estimation of the density of a particular plant in a community and obtaining confidence limits for the estimate, (2) the comparison of the densities of two plants or of the same plant in two communities and (3) the randomness or otherwise of the occurrence of plants in some community. Tests are derived and illustrated for these problems and a comparison of the accuracy of the methods based on quadrats and those based on spacing is made.--Auth. Abs.

Morisita, Masaaki.
1954. estimation of population density by spacing method. Kyushu Imp. Univ., Faculty Sci. Mem. Ser. E 1: 187-197.

——— 1957. a new method for the estimation of density by the spacing method applicable to non-randomly distributed populations. Physiol. and Ecol. [Japan] 7(2): 134-144. [In Japanese with English summary.]

Even if T individuals are distributed irregularly over an area (A), the area may be divided into several small fractions (A_i, i=1, 2, 3,...,) on which the individuals contained will be distributed randomly or uniformly. By placing N sample points randomly on the total area A, dividing the circle of infinite radius surrounding each sample point into k sectors, and measuring the distance (r) to the nth nearest individual in each sector from the sample point, formulae can be derived when the individuals are distributed at random on A. These formulae are given. The author considers that regular sampling is also available for density estimation by this method unless the individuals are distributed regularly on A. Results of the estimation by this method are given for various artificial populations. The method can be put to practical use at least when k=4 and n=3 are used.--Biol. Abs.

Pielou, E. C.
1959. the use of point-to-plant distances in the study of the pattern of plant populations. Jour. Ecol. [London] 47(3): 607-613.

Borgeson, A. E., Colclough, D. M., and Young, H. E.
1958. a field test of the bitterlich variable plot cruising method in maine. Maine Univ. Forestry Dept. Tech. Note 48, 4 pp.

Tests were made in 50 stands of varying composition, structure, and density (data tabulated) and the results (a) compared with tape measurements of trees on a 1/5-acre plot in each stand (b). Time taken for (a) averaged 13.3 minutes and for (b) 31.6 minutes. For all 50 plots combined, basal area as measured in (a) was 10 percent higher than that obtained by (b), the difference on separate stands varying from +87.5 percent to -24.5 percent.

Cottam, Grant, and Curtis, J. T.
1949. a method for making rapid surveys of woodlands by means of pairs of randomly selected trees. Ecology 30(1): 101-104.

Pairs of trees are used instead of quadrats to furnish data from which frequency, density, and dominance may be calculated. Points are set up at predetermined intervals along a compass line, with 2 trees near each point which bear certain spatial relations to each other becoming the pair on which measurements are made. There is good agreement between results with the pairs method and the regular quadrat method.

Dafauce Ruiz, Carlos.
1958. un nuevo método de medición rápida de espesura de rodales y de aprecición de volúmenes (el prisma dasométrico). [a new method for rapid measurement of volume and growth of timber stands.] Montes [Madrid] 14(80): 113-118, illus.

Suggestions are made for reducing errors in use of the "wedge prism" in the "point sampling" method, and for automatic reduction of sample data to horizontal values.--Biol. Abs.

Daniel, T. W., and Sutter, Harold
1955. bitterlich's "spiegelrelaskop" a revolutionary general-use forest instrument. Jour. Forestry 53(11): 844-846.

Instrument for making measurements as plotless survey of timber resources. Excellent description of instrument.

Finch, H. D. S.
1957. plotless enumeration with angle gauges. Forestry [London] 30(2): 173-192, illus.

The basic method and theory for determining basal areas with angle gauges are explained. Limitations in use are pointed out, and modifications and developments discussed. An explanation is given of the use of the angle-gauge principle for determining height and volume. Next, the instruments themselves are discussed and finally the Spiegelrelaskop and its wide range of uses. For the future, the author considers consolidation of ideas more likely than any very startling new developments. A full list of references to literature is given.--Auth. sum.

Gallardo Martin, José, and Garcia-Gutiérrez, González Antonio.
1957. muestreo puntual en el cálculo de extencias. [point sampling for calculation of forest stands.] Montes [Madrid] 13(78): 405-410, illus.

The theory and application of the point-sampling method, with wedge prism, for determining basal area and volume of forest stands are described.--Biol. Abs.

Grosenbaugh, L. R., and Stover, W. S.
1957. point-sampling compared with plot-sampling in southeast texas. Forest Sci. 3(1): 2-14.

This exploratory study demonstrated how comparisons between point-sampling and plot-sampling estimates should be analyzed. Point-sampling estimates of basal area and volume per acre were found to be unbiased with respect to plot-sampling estimates when precautions were observed. Local cost information was not secured for ¼-acre plot-sampling, so relative efficiencies cannot be estimated, although certain advantages of point-sampling were quite obvious (possibility of 1-man crews, growth and error calculations). Coefficients of correlation and variation in southeast Texas may not be valid for other areas, but they are at least indicative of the comparative magnitudes and trends apt to be exhibited elsewhere, and may be useful in sampling design. A rough estimate of optimum cluster-size indicated that 3 points per cluster would have been slightly better than 2, but this conclusion might be modified if crew, grid, gauge, or conveyance is changed. Finally, a technique was developed for reducing bias in basal-area estimates when tree frequency only has been tallied by rather broad d.b.h. classes (2 inches or more).--Auth. concl.

Hirata, T.
1958. precisions of variable plot methods (WZP). Tokyo Univ. Forests Bul. 54 17 pp. [In Japanese. English summary.]

Husch, Bertram.
1955. results of an investigation of the variable plot method of cruising. Jour. Forestry 53(8): 570-574, illus.

Within recent years a new approach has been developed which promises to speed up timber volume estimation. The variable-plot method, proposed by W. Bitterlich in 1948, consists of establishing sampling points in the tract to be inventoried. All those trees whose diameters appear larger than an angle gauge are counted at each point. The mean number of trees per point is multiplied by a constant to obtain average basal area per acre. Other timber survey statistics can be developed by varying the procedure. Four contiguous 10-acre tracts were sampled using 3 critical angles; 52.09, 104.18 and 208.38 minutes. A complete tally of all trees was made of the same area for comparison. Basal area and volume estimates were then calculated. The 208.38' angle proved most accurate and efficient. The results of the estimates with the 52.09' angle were much less accurate. The estimates with the 104.8' angle gave results between the other two. Results indicate that the variable-plot cruising method works best with a large critical angle used at the maximum number of estimating points.--Auth.

Husch, Bertram.
1956. comments on the variable plot method of cruising. Jour. Forestry 54(1): 41.

Lindsey, Alton A., Barton, James D., Jr., and Miles, S. R.
1958. field efficiencies of forest sampling methods. Ecology 39 (2): 428-444.

A large scale map of an undisturbed 20-acre stand of white oak--beech--sugar maple was sampled intensively by 9 forest sampling methods. The number of units and number of trees required for 15 percent standard error were computed. Each method was timed in the actual stand to determine time per tree. The total number of stems of all species required for 15 percent standard error for a selected dominant species multiplied by the time per stem gave a total time-at-units figure for each method. To this was added the time required to make the circuit of the required number of sample units; the sum is the field time, the inverse of field-statistical efficiency. For sampling the density and basal area of either sugar maple or beech with not more than 15 percent standard error, the methods ranked in the following order of field time--(1) combination of the rangefinder circle and the Bitterlich method, 2.04 hours; (2) tenth-acre rangefinder circle, 3.41 hours; (3) fifth-acre strip, 3.65 hours; (4) full Bitterlich, 3.66 hours; (5) quarter method, 4.36 hours; (6) fifth-acre square, 5.17 hours; (7) tenth-acre square, 5.81 hours; (8) fortieth-acre circle, 6.85 hours; and (9) fortieth-acre square, 9.84 hours.--Biol. Abs.

Alekseenko, L. N.
1959. [method for determining leaf area of herbage plants.] Lenin Acad. Agr. Sci. Proc. 24(9): 27-28. [Russian]

The method described is based on the assumption that the area of 1 g. of the crude leaf (or of 1 g. of leaf in an air-dry condition) is constant for a given species. This assumption is substantiated as follows. In each herbage species the area is determined (11 to 35 times) of 1 g. of the crude or dry leaves at different stages of plant development. Whole plants from the experimental plots are cut and all the green leaves are quickly removed, weighed and imprinted on light-sensitive paper which, after being developed, shows the leaves in clear contour. These contours are cut from the prints and weighed, comparison being made with the weight of 100 sq. cm. of paper. Thus the area of leaves in a given sample is determined and the number of sq. cm. in 1 g. crude leaf is calculated. At the stage of maximum development, the leaf area per 1 sq. m. of soil calculated by this method is (in sq. m.): for Phleum pratense 4.85; for Festuca pratensis 4.88; Dactylis glomerata 10.62; Bromus inermis 12; Trifolium pratense 9.68; and Medicago sativa 17.5. To determine the accuracy of this coefficient (i.e. leaf area in sq. cm. as derived from 1 g. of the leaf's crude or dry weight), the data have been statistically analysed and this shows that the percentage error does not exceed 2.15. It is concluded that utilizing this coefficient as obtained for conditions in the N. W. zone of USSR, or determining it by this method for plants grown in other climatic conditions, is a quick process (with an accuracy within 1.5 to 2 percent in field conditions) by which crude weight of the leaves can be used to determine leaf area. To relate leaf area with a unit of soil surface, the leaf weight is considered with any given area of soil.--Herb. Abs.

Bedell, T. E., and Heady, H. F.
1959. rate of twig elongation of chamise. Jour. Range Mangt. 12(3): 116-121, illus.

Chamise plants (Adenostoma fasciculatum), the tops of which had been removed, produced sprouts which grew more rapidly than did twigs of either grazed or ungrazed mature plants. Twig elongation began on approximately 24 March for mature plants and the hedge-like, grazed plants, and slightly later in the case of topped plants. Twig elongation on mature plants ceased on 23 June, while on hedged plants it ceased on 24 July. Topped plants continued growth until late autumn. Removal of terminal buds from twigs of mature plants caused reproductive or vegetative axillary growth occurred when buds were removed in spring, at which time the growth rate of the plant was at a maximum.--Herb. Abs.

Bredemeier, L. F.
1958. measurement of time and rate of growth of range plants with applications in range management. Jour. Range Mangt. 11(3): 119-122.

Aerial length measurements of grasses were made over two years. Agropyron smithii and Stipa comata made some growth during the winter. The main growth of these grasses and of Bouteloua curtipendula, Andropogon scoparius, and Calamovilfa longifolia began at roughly the same time and was made within three months, so that maximum elongation was reached at about the same time. Seasonal variations in amount and time of rainfall had little influence on linear growth.--Herb. Abs.

Cochran, W. G., and Watson, D. J.
1936. an experiment on observer's bias in the selection of shoot heights. Empire Jour. Expt. Agr. 4: 69-77.

Samples picked by the process of randomization must be representative of the population from which they are drawn and give an unbiased estimate of the quantity which it is desired to measure. Of twelve observers, all of whom had some training in sampling, not one managed to pick a sample that could be called representative of the material from which they were sampling and all except three obtained relatively large biases in their estimate of the shoot-height being measured. Biases in shoot-height and relative variance show large differences from individual to individual and that of each individual is not consistent throughout the experiment but increased regularly as the mean height of the sampling unit decreased. This investigation supports the evidence that the only sure way to avoid bias is for selection to be random. The plea has been made that observer bias is not important provided the same observer makes all the estimates. However, as shown by the investigation the observer bias does not remain constant. Even if it did the uses to which his results could be put are very limited. Percentage differences or regression coefficients based on his results would have biases in different ways. No one can forsee the results to which his data might be applied and differences between observers will come into play under studies of long duration.

Davidson, J. L., and Donald, C. M.
1958. the growth of swards of subterranean clover with particular reference to leaf area. Austral. Jour. Agr. Res. 9(1): 53-72, illus.

An experiment was conducted to study the growth of T. subterraneum sown at four different densities (1, 4, 14, and 50 plants/sq. link [1 link = 7.9 in.]); the control swards were not defoliated, while others were subjected to a single defoliation at various dates, 2-4 months after sowing. During the final month the rate of dry-matter

production (tops only) increased to a maximum when the leaf area index (the ratio of the area of the leaves to the area of the ground surface = L.A.I.) was ca. 4-5, falling by ca. 30 percent as the L.A.I. increased to 8.7. The rate of leaf production was greatest at about L.A.I. 4-5, falling to zero at L.A.I. 8.7. Climatic conditions during the growth influenced the relationship of L.A.I. to growth; as conditions became more favorable the values of the optimum L.A.I. for growth and of the ceiling L.A.I. progressively rose. Irrespective of the density, all swards tended towards a common ceiling L.A.I. and yield by the end of the season. The effect of defoliation depended on the L.A.I. at which defoliation occurred, on the value to which the L.A.I. was reduced and on current climatic conditions. If swards near the ceiling L.A.I. were defoliated, total dry-matter production was slightly increased and there was a great increase in leaf production. Defoliation of swards from about the optimum L.A.I. to very low L.A.I. values led to a substantial reduction in both dry matter and leaf production. It is suggested that all these effects depend on the light relationships within the sward and their influence on the balance of photosynthesis and respiration. Pasture at the optimum L.A.I. will give greater production than swards of lower or higher L.A.I.; defoliation can give greatly increased leaf production, unless L.A.I. is reduced to very low values. --Herb. Abs.

Donovan, L. S., Magee, A. I., and Kalbfleisch, W.
1958. a photoelectric device for measurement of leaf areas. Canad. Jour. Plant Sci. 38(4): 490-494.

Harberd, D. J.
1957. the within population variance in genecological trials. New Phytol. [London] 56(3): 269-280, illus.

This study was made with Festuca ovina, the characters recorded for analysis being: date of ear emergence; lengths of stem panicle and leaf; and growth habit.--Herb. Abs.

Heady, Harold F.
1957. the measurement and value of plant height in the study of herbaceous vegetation. Ecology 38(2): 313-320, illus.

The concept of plant height, methods of measuring height, and the usefulness of height measurements are reviewed. A method of measuring the height of plant materials with the point-plot method, whereby the height of hits by the pins are used to measure the height of mass for species individually and for vegetation, is described. This gives a vertical dimension to foliage cover. The method is objective, easy to operate, and adds another measurement to those normally collected with the point-plot system. Examples are given to illustrate how the method is useful in the comparison of species and vegetation between areas, years, seasons, and grazing treatments in the California annual type vegetation.--Auth. abs.

Hopkins, J. W.
1939. estimation of leaf area in wheat from linear dimensions. Canad. Jour. Res. Sect. C, Bot. Sci. 17: 300-304.

Jenkins, H. V.
1959. an airflow planimeter for measuring the area of detached leaves. Plant Physiol. 34(5): 532-536.

Kemp, C. D.
1959. estimation of leaf area by regression techniques. Grassland Res. Inst. Expts. in Prog. Ann. Rpt. 1957-1958, 11: 90.

For grasses of widely differing leaf shape and size the equation A = 0.905 (LB) can be used to estimate leaf area (sq. mm.), where A = leaf area, L (mm.) = length and B (mm.) = breadth of the leaf measured at a point halfway along the length of the leaf.--Herb. Abs.

Mitchell, J. W.
1936. measurement of the area of attached and detached leaves. Science 83: 334-336.

This device measures the amount of light intercepted by the leaf from falling on a Weston Photronic cell. It may be usable in compiling areas of quadrats. Very great accuracy possible.

Thirumalachary, N. C.
1940. a rapid method of measurement of leaf areas of plants. Indian Jour. Agr. Sci. 10: 835-841, illus.

Williams, R. F.
1954. estimation of leaf area for agronomic and plant physiological studies. Austral. Jour. Agr. Res. 5(2): [235]-246, illus.

A method based on leaf photographs is described for the estimation of leaf area. The method of preparing the standards is given, and a set of standards covering the full range of leaf form in young plants of the Pearson variety of tomato is presented. The method is rapid and does not damage the experimental plants. With five observers, the method was tested for the presence of bias resulting from fatigue or from variation in leaf size or form. Some of the observers showed personal idiosyncrasies of judgment which did not, however, invalidate the method for comparative studies. Estimates by all observers of leaf area per plant were very highly correlated with estimates based on an independent reference method.--Auth. sum.

Williams, T. E., and Baker, H. K.
1957. studies on the root development of herbage plants. I. techniques of herbage root investigations. Brit. Grassland Soc. Jour. 12(1): 49-55.

Various methods of root sampling are reviewed and discussed in relation to the type of information required. The root sampling techniques at the Grassland Research Institute are described and examples of sampling errors are given. Details of a root washing machine are given.

Balázs, F.

1949. a gyepek termésbecslése növény szociológiai felvételék alapján. [the evaluation of the yield of grass fields on basis of phytosociologic surveys.] Agrártudomány [Budapest] 1: 26-35, illus.

A method was devised by the use of 2 X 2-meter squares in the respective grass field areas. The ratio of surface occupied by the single plant species is estimated and the dominance values expressed by numerical rates (D_B numbers). The mean height of the single plant species must be determined also and the mean height of the grasses calculated from the formula $\frac{10 \times \Sigma T}{D_B}$ where ΣT indicates the total grass yield obtained by summing up the D_B X m results calculated for each individual plant species, where m signifies the height of the individual species. The actual hay yield is calculated by use of the formula: $\frac{(M-s)Bb}{100E}$ where M signifies the mean height of the grass, s the height of grass remaining after cutting off the hay, B indicates a constant characteristic for each plant species or association and is calculated on the basis of the empirical green hay yields of them, b is another constant representing the degree of cover of the grass surface, and E is a drying factor for hay, ranging from 2.5 to 3.5. Some examples are given in which the formula gave a good practical evaluation.

Cable, Dwight R.

1958. estimating surface area of ponderosa pine foliage in central arizona. Forest Sci. 4(1): 45-49.

Measurements of tree diameter, total foliage weight, and weight, length, and diameter of needle fascicles of ponderosa pine (Pinus ponderosa) were made to develop equations by which the foliage area of a tree can be estimated from diameter alone. For 20 trees between 1 and 20 inches diameter breast high, weight of foliage (W) in kilograms was found to vary with tree diameter (D) according to the following equation: $\log W = 1.8811 \log D - 0.8882$. For 11 trees between 1 and 18 inches diameter breast high, mean weight per fascicle (MWF) in grams was found to vary with tree diameter (D) according to the following equation: $MWF = 0.00514\, D + 0.1111$. Fascicle area (FA) in square centimeters was related to oven-dry fascicle weight (FW) in grams according to the following equation: $FA = 5.645 + 54.502\, FW$. Surface area of foliage of a tree is estimated from these equations by dividing total weight of foliage by the mean weight per fascicle and multiplying by the surface area of the average fascicle.--Biol. Abs.

Canfield, R. H.

1941. application of the line interception method in sampling range vegetation. Jour. Forestry 39(4): 388-394, illus. [See LINE INTERCEPT].

_____ 1944. measurement of grazing use by the line interception method. Jour. Forestry 42(3): 192-194, illus. [See LINE INTERCEPT]

_____ 1944. a short-cut method for checking degree of forage utilization. Jour. Forestry 42(4): 294-295, illus.

A chart is presented for determining percentage of ungrazed and percentage of partially grazed forage when the percentage grazed at a stubble height of two inches or less is known.

Clark, Ira.

1945. variability in growth characteristics of forage plants on summer range in central utah. Jour. Forestry 43(4): 273-283, illus.

Four-year records of variation in vertical distribution of forage weight along the height of the stem of 10 species common on high summer ranges showed that lack of constancy in form of plant was the rule rather than the exception. Growth form for the same species varied markedly between samples from different years, from different elevational zones, and from different sites. These studies show the wide variation which is to be expected in total forage supply and in the proportion which is removed when the range is grazed to a given stubble height. Because of the variation in form of plant with season, site, and previous grazing, large errors may result from the use of tables based on average percentage of forage volume above given heights on the plant (volume-height method).

Collins, Robert W., and Hurtt, Leon C.

1943. a method for measuring utilization of bluestem wheatgrass on experimental range pastures. Ecology 24(1): 122-125.

An objective method for measuring degree of grazing is under development as a first step in defining the proper degree for utilizing forage plants and for better range management. The development of a composite curve is briefly described which shows the height-weight relationship of bluestem wheatgrass, Agropyron smithii, using both culmed and culmless forms combined in the correct ratio for the site and year in question. After the percentage of plants grazed and their stubble heights are determined by sampling the pastures along transect lines, the total percentage utilization for grazed plants is read from this curve. The method is objective and reveals slight differences in degree of grazing.--Biol. Abs.

Crafts, Edward C.
1938. height-volume distribution in range grasses. Jour. Forestry 36(12): 1182-1185, illus.

The relation between height and herbage volume (or air-dry weight) of 11 important southwestern range grasses was studied by clipping at various heights. A similar concentration of herbage volume was found for all species at the lower heights; degree of utilization of the forage cannot be inferred directly from the percentage of total height that is grazed. Line charts relating height to volume for 8 species are given.

Dasmann, William.
1945. a method for estimating carrying capacity of range lands. Jour. Forestry 43(6): 400-402.

The author questions the reliability of estimates of carrying capacity based on methods now used in range surveys, and describes briefly a new method based on (1) the estimated weight of each species, (2) a proper-use (or allowable-cropping) factor, and (3) a preference rating which indicates the amount of each species that will be consumed when the key species receives no more than allowable cropping.--Biol. Abs.

Evans, R. A., and Jones, M. B.
1958. plant height times ground cover versus clipped samples for estimating forage production. Agron. Jour. 50(9): 504-506.

The product of plant height and ground cover (HG) was compared with clipping as a method for determining forage production at different growth stages in 15 fertilizer trials on range land of varying botanical composition. The effects of the fertilizer treatments were similar for both methods. On plots with early (2 in. tall), intermediate ($>$ 4 in. tall), or mature growth there was a quantitative relationship between the values obtained from both methods, but for early growth the relationship was not the same as for the more mature herbage. In lodged and overmature stands the relationship was erratic. Advantages of the HG method were: (a) a larger area can be sampled, (b) vegetation remains intact during sampling, (c) sampling can be carried out at the same time as step-point vegetational analysis. However, HG values could not be expressed in familar terms (such as lb./acre), and where botanical analysis was not necessary, the method took as long as, or longer than, did clipping.--Herb. Abs.

Frakes, R. V.
1959. predicting dry matter yield in space planted alfalfa by height, width, and longest stem measurements. Agron. Abs. 1959: 58.

Halls, L. K., and others.
1956. grazing capacity of wiregrass-pine ranges of georgia. Ga. Agr. Expt. Sta. Tech. Bul. (n.s.) 2, 38 pp., illus.

In studies carried out during 1950-1954 in the Coastal Plain region of Georgia, determinations were made of the grazing capacity and optimum rate of stocking of burned-over wiregrass/pine rangelands. The ranges were burned-over each January, except in 1951, and stocking rates of 4, 6, 7, 9, 14 and 18 acres per steer were used. Grazing lasted from mid-March to mid-January of each year, except in 1952, when no grazing took place. Forage utilization ranged from 30 percent under light grazing to 65 percent under the heaviest rate of stocking. On dry land areas, grasses made up 85 percent of the herbage consumed. Most forage in spring was provided by Aristida stricta and Sporobolus curtisii. In summer, Andropogon stolonifer, A. virginicus and Axonopus affinis were the most important species. Nearly all native species in the area studied tolerated burning well and, in many cases, had greater vigour and palatability after winter burning. The ground cover on heavily grazed areas decreased, as did herbage production, though on localized areas A. affinis invaded and completely occupied areas vacated by over-grazed bunch grasses. Herbage production on ungrazed open areas averaged about 1060 lb. oven-dry forage per acre, compared with 775 lb./acre on grazed areas. Estimations of herbage production could be made by using the following formula: $Y = 1060-15X_1-13X_2$, where Y= estimated herbage production, X_1 = percentage overhead tree canopy and X_2 = percentage shrub cover. For maximum weight gains, the equivalent of 9 acres of open range, without trees or shrubs, was needed to feed a 500 lb. steer from March to January.--Herb. Abs.

Harris, F. B.
1941. a short cut method of computing grazing capacity ratings from range survey forage estimates. Nev. Agr. Expt. Sta. Bul. 155, 15 pp., illus.

The proposed method has many advantages over those in use at present. It is directly applicable to the point observation plot and ocular reconnaissance methods of range survey, and involves no changes in field procedure. The method described greatly reduces the time needed to compute carrying capacity rating (surface acres per animal unit month) from estimates of forage density. This is accomplished by prearrangement of the coded products of density times proper use factor (forage factors) on the write-up sheet. The sum of these small whole numbers is converted to surface acres per animal unit month by reference to tables which form part of the sheet.

Heady, Harold F.
1950. studies on bluebunch wheatgrass in montana and height weight relationships of certain range grasses. Ecol. Monog. 20(1): 55-81.

During 1946 and 1947, 1110 plants in 5 species of grass from central Montana were processed to determine the nature of variations in height-weight. At the same time an attempt was made to determine the causes of the variations in bluebunch wheatgrass. The term height-weight is used to express the proportion of the total air-dry weight of a grass plant in successive 1-inch segments from the base to the top. When samples of 30 plants from 1 site and 1 year were compared with height class tables constructed from all plants processed, variations in percentage of weight below stubble heights of 2-6 inches were less than 10 percent. The variations were not consistent with average height of plants, average weight, environmental conditions in the habitats, elevation, or composition of species in the stand. However, clipping of bluebunch wheatgrass did result in considerable differences in the height-weight relationships. The height-weight method is used to determine utilization of grasses by livestock and under the conditions of the experiment it was shown to be reasonably accurate for that purpose.--Biol. Abs.

Kelly, A. F.
1958. a comparison between two methods of measuring seasonal growth of two strains of dactylis glomerata when grown as spaced plants and in swards. Brit. Grassland Soc. Jour. 13(2): 99-105, illus.

A trial is described which was designed to test the hypothesis that measurements of the leaf-plus-shoot length of spaced plants may give a good indication of dry-matter yields of strains of Dactylis glomerata, when compared with results from cutting and weighing the produce of sward plots. Two contrasting strains of Dactylis glomerata were used: the British S 143, and the German von Kamekes. The strains were established during 1955 both as spaced plants (10 plants per plot) and as pure swards, with 6 replications of each. The two methods of establishment formed the main treatments, occupying whole plots, and each plot was divided into 4 sub-plots each of which carried one of the 2 strains combined with one of the following 2 management treatments: treatment 1, cut at monthly intervals from 27 April to 23 August; treatment 2, cut on 12 April and subsequently at the mean date of emergence of the inflorescence for each strain, followed by cutting at monthly intervals until the end of August. Spaced plants were measured before cutting by thrusting a measuring rod into the crown of the plant and measuring the leaf-plus-shoot length of one of the longer shoots. Produce cut from sward plots was weighed and sampled for dry-matter content. Results from the swards showed that von Kamekes produced more dry matter in early spring, but that subsequently the advantage passed to S 143. Significant positive correlations were obtained in early spring between the sward yields and leaf-plus-shoot measurements from spaced plants. Subsequently there was no agreement between the two methods, and some significant negative correlations were obtained. The data are discussed in relation to the physiological stages of development of the strains: (a) in the spring period the main factor contributing

to yield was shoot elongation, with the majority of the tillers in the reproductive phase; (b) in summer the main factor was new tiller formation, with the majority of tillers in the vegetative phase; (c) in the early autumn neither factor was dominant and both contributed to yield. Attention is drawn to the danger of comparing yields from swards where the management may influence the results obtained, and to the difficulty of assessing hay yields by means of height measurements of spaced plants.--Herb. Abs.

Kelting, R. W.
1957. winter burning in central oklahoma grassland. Ecology 38(3): 520-522.

An area of grassland dominanted by _Andropogon scoparius_, _A. geradii_, _Sorghastrum nutans_ and _Panicum virgatum_, was burned in early February 1952, after being protected from grazing since mid-1949. Of a number of climatic and edaphic factors studied after burning, only the maximum soil temperature, which was appreciably higher on burned than unburned areas, showed any great response to burning. The area cover of grasses increased more on burned than unburned areas from the second week in April, onwards. By mid-June, the area cover of _A. scoparius_ had increased from 11.9% on unburned plots to 15.9% on burned plots, while that of _A. geradii_ decreased significantly from 4.3 to 0.6 percent. The correlation coefficients between area cover and dry weight for all grasses in burned and unburned plots were +0.91 and +0.81, respectively. It is thought that area cover could be adapted for use in calculating the actual amount of foliage present on a given area, though there is evidence that this may only apply to grasses during the early part of the growing season. The need for adding a height factor to the area cover is suggested.--Herb. Abs.

Kira, Tatuo, Ogawa, Husato, and Sakazaki, Nobuyuki.
1953. intraspecific competition among higher plants. I. competition-yield-density interrelationship in regularly dispersed populations. Osaka Imp. Univ. Inst. Polytech. Jour. Ser. D 4: 1-16.

The nature and trends of intraspecific competition were investigated, based mainly on the field experiment with soybean for 1952, and in part on the preliminary experiments with sand-cultured vegetables in 1950-52. Soybean plants were regularly distributed over the field in right triangular dispositions, and 5 different grades of planting density were employed. Sampling was made 6 times during the experimental period of 119 days (June 27--October 24, 1952). Fifty plants per each density grade were sampled at a time, and total weight of each plant was measured. The intensity of competition as indicated by mean plant weight rose with increasing density. But the relative variation of individual weight values within a population showed no significant correlation with changes of density. This fact tells that, contrary to the common view, the intensified competition did not accelerate the dominance of the larger individuals over the smaller.

Competition in the narrow sense did not occur among individual plants, but the population as a whole reacted to the limited supply of growth factors. The regression of mean plant weight (w) on density (d) was found to be represented by the following empirical formula, $w\ d^a = k$, or $w = K\ s^a$ where s = mean available space/plant and a, K = constants. The results of the preliminary experiments as well as of previous research were also successfully fitted to the equation. Its applicability was proved to be wide, so far as individual plants in the population are regularly distributed. Namely, w in the equation may be dry weight, fresh weight or even the weight of a certain part of plant, such as top, leaf, trunk, root or seed. The index figure a, which represents the degree of space utilization by plant at certain stages of growth, increased from zero in the seed stage to 1.0 approximately, where the equilibrium was reached at which dry weight was inversely proportional to density. When based on dry weight of plant, the time trend of the increase of a could be approximated by the following regression, $a = m \log T+n$. The functional relations represented by these equations are named the competition-density effect. It seems to represent 1 of the fundamental quantitative principles underlying the time-space trend of intraspecific competition among higher plants. The index figure a, here called the C-D index, can also be used as a measure of the relative intensity of competition, when the experimental results under different environmental conditions or with different species of plants are to be compared. Changes in the index value, when weights of various parts of a plant were correlated with density, were also discussed. The relation between total plant yield/unit area (Y=dw) and density is given by the following equation, $Y\ d^{a-1} = K$ which may be called the yield-density effect. Starting from the equation, some practical considerations were made on the determination of the adequate planting distance for economic crop cultures.--Biol. Abs.

Kittredge, Joseph.
1945. some quantitative relations of foliage in the chaparral. Ecology 26(1): 70-73.

Weights and areas of leaves are highly correlated and the weight per unit of area is nearly constant for a species. The log of dry leaf weight is a linear function of the log of crown diameter for Ceanothus crassifolius and Arctostaphylos glandulosa. For the Ceanothus, the total dry leaf weight per unit of land area is a linear function of the percentage coverage of the crowns. These relations facilitate estimates of total weights of foliage of all the plants on areas of land.

Leasure, J. K.
1948. determining the species composition of swards. Agron. Jour. 41(5): 204-206.

The point quadrat method of sward analysis was compared with certain other methods. A combination of point quadrat and visual estimation can save considerable time without impairing accuracy.

Lommasson, T., and Jensen, Chandler.
1938. grass volume tables for determining range utilization. Science (n.s.) 87: 444.

There is an urgent need for a mechanical means of determining the degree of grazing of forage plants on national forests and other ranges in the West. In the Montana region a partial three-cycle, semi-circular logarithmic scale has been developed which converts inches of stubble into percentage volume utilization. A full account of this work is to be published.--Herb. Abs.

_______ and _______
1943. determining utilization of range grasses from height-weight tables. Jour. Forestry 41(8): 589-593.

Lundblad, K.
1937. metoder för botanisk analys av vallar. [methods for botanical analyses of grassland.] Svenska Mosskulturför. Tidskr. [Sweden] 51: 187-235. [English summary, pp. 230-234.]

A discussion of the advantages and disadvantages of certain laboratory and field methods of grassland analysis used in the Scandinavian countries and in Finland is given. An estimation of hay composition based on degree of covering in the field and on comparisons with tabulations presented proves more satisfactory than a direct estimate of weight percentages of the field components.--Herb. Abs.

Martin, E. P.
1955. use of regression line to estimate basal cover of sod-forming grasses. Kans. Acad. Sci. Trans. 58(4): 526-527.

In an attempt to eliminate the considerable time and labor entailed in using the pantograph and planimeter technique for estimating basal cover, the possibility of using stem numbers for such estimations was investigated. The correlation coefficient between basal cover and stem numbers for Agropyron smithii was 0.88, with a standard error of 0.14, and it was concluded that it was possible to make a satisfactory estimate of basal cover from stem numbers for this species. --Herb. Abs.

Mattox, James E.
1955. a study of per cent of plants grazed method of utilization determination and its application. Mont. Agr. Expt. Sta. Mim. Cir. 88, 140 pp., illus.

Osborn, Ben.
1947. determining range utilization by frequency tallies. Jour. Soil and Water Conserv. 2(1): 51-55.

The frequency tally which has been used in Soil Conservation Districts in Texas is a rapid method of determining composition and degree of use of range vegetation. It is based on a count of a random sample of individual plants, classified into three use classes; namely, fully grazed, partially grazed, and not grazed. Composition is calculated as the percentage frequency of occurrence of each species. Percentage of use for each species is computed as the total of the percentage of plants of that species fully grazed plus half the percentage partially grazed. Weighted average percentages of actual use and proper use can be compared to indicate the existing degree of use of the sample. Both grassland and browse types, or a combination of these, can be evaluated by this method.--Auth. sum.

Pastro, Jerome K., Allison, John R., and Washko, John B.
1957. ground cover and height of sward as a means of estimating pasture production. Agron. Jour. 49(8): 407-409.

Test areas of (a) permanent Poa pratensis and (b) sown Dactylis glomerata/Trifolium repens variety pastures were enclosed with cages and the ground cover, sward height and forage yield measured. There was a correlation between cover and yield figures for both pasture types; the correlation coefficients were 0.728 for (a) and 0.733 for (b). Yields of forage on (a) were very small when the cover was less than 70 percent and though the standard error was large, it represented only a very small proportion of the yield. It was concluded that cover could be used to assess forage production on low-yielding P. pratensis pastures. In the case of (b) the standard error represented a large amount of forage, and yield assessments in terms of ground cover were unreliable. Multiple correlation coefficients for cover and height were 0.912 for (a) and 0.875 for (b).--Herb. Abs.

Pechanec, J. F.
1936. comments on the stem-count method of determining the percentage utilization of ranges. Ecology. 17(2): 329-331.

Stoddart's method for determining percentage utilization of grazed ranges has been tested under field conditions to verify its accuracy and to compare it with other methods already in use. It is contended that the stem count system of obtaining percentage utilization is not of sufficient accuracy to merit its unqualified use in pasture or open range studies since deviations or errors tend to be positive and cumulative.

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1937. a comparison of some methods used in determining percentage utilization of range grasses. Jour. Agr. Res. 54: 753-765.

This experiment to test the limits of accuracy, the inherent personal error, and the rapidity of determining percentage utilization of range forage by grazing was carried out on sagebrush-wheat grass range which

was dominated by Agropyron spicatum and Artemisia tripartita. Clipping to simulate removal by sheep was used as a substitute for grazing which allowed the use of an accurate check in the form of the modified volume-by-weight method. Other methods used were (1) ocular-estimate-by-plot, (2) ocular-estimate-by-average-of-plants, (3) stem count, (4) measurement and (5) ocular-estimate. From data presented it is recommended that ocular-estimate methods of obtaining percentage utilization, supplemented by comparison with determinations made by the modified volume-by-weight method, be considered for use in range pasture or open-range studies.--Herb. Abs.

Pergament, E.
1959. components of variation of mature height and yield in medicago sativa l. Agron. Abs. 1959: 64.

Precsenyi, S.
1955-1957. the correlation between ground-cover and vegetation yield. Portug. Acta Biol. Ser. B. 6(1): 94-96, Bibl. 1.

In an investigation to determine mathematically the relationship between ground cover and vegetation yield, using data from 25 plots (1 X 1 m. each) covered by Lotus corniculatus and Dactylis glomerata, a good positive correlation was found.--Herb. Abs.

Proudfoot, K.G.
1957. a comparison of total dry-matter yields obtained in the first harvest year, from five strains of perennial ryegrass under single plant, pure sward, and clover sward conditions. North Ireland Min. Agr. Res. and Expt. Rec. (1956)6: 19-30.

Irrespective of planting method, greater dry-matter production was obtained from all strains of Lolium perenne on trial in the first harvest year by decreasing the frequency of cutting. Yields from swards increased with the addition of clover. Strains were ranked similarly under both pure and clover-sward conditions, but not when assessed as single plants. The discrepancy tended to disappear when single-plant production was related to the actual area occupied. It is suggested that the use of the yield/basal-diameter ratio in strain classification will give a more accurate picture of potential yield under sward conditions.--Herb. Abs.

________ and Wright, C. E.
1958. an assessment of the relative values of three methods of determining the leafiness of perennial ryegrass. Min. Agr. Res. and Expt. Rec. (1957)7: 27-30.

A rapid technique for the estimation of leaf/stem ratio in perennial ryegrass is described and compared with standard methods (determination of number of heads per unit weight of plant material, or hand

separation of leaves and stems and determination of dry weights of each). In the rapid method, the bundle of plant material from each spaced plant is weighed with as little disturbance as possible, then grasped by the heads so that the leaf material can be shaken out. The heads are then weighed and a leaf/stem ratio obtained. Significant correlation coefficients were obtained for all comparisons of the three methods at two aftermath cuts, but the cut at the hay stage (1 month after mean ear emergence for each strain) did not give significant correlations between the methods.--Herb. Abs.

Roach, Mack E.

1950. estimating perennial grass utilization on semidesert cattle ranges by percentage of ungrazed plants. Jour. Range Mangt. 3(3): 182-185.

A utilization measurement system based on the percentage of ungrazed grass clumps was studied in an effort to lessen disadvantages inherent in presently used systems. A graph showing the relation between the percentage of ungrazed plants and the percentage of total weight of herbage removed must be prepared for each local grass type. In making a survey by the percentage ungrazed method the fieldman needs only to determine the percentage of plants remaining ungrazed in the pasture or range area. This can be done by use of enough paced transects to give a representative sample of the pasture. The mean percent of ungrazed plants for the pasture may then be entered on the graph and percentage use read off directly. The percentage ungrazed system has been tested for four years on the Santa Rita Experimental Range. The average difference between measured use expressed in percent (percentage ungrazed method) has been 1.6. The greatest difference was 2.4. This shows fully adequate accuracy for practical use.

Rodionov, M. S.

1959. ob opredelenii massy listvy zaščitnyh lesopolos. [determining foliage weight in shelterbelts.] Bot. Žhur. S.S.S.R. 44(3): 333-337. [Russian.]

In continued work correlation coefficients of ≥ 0.90 and ≥ 0.93 between diameter at root collar and fresh weight of foliage were found for 2- to 4-year-old Quercus robur and Fraxinus pennsylvanica in shelterbelts. For older belts, collection of all the leaves from an adequate number of sample trees becomes very laborious, and accordingly Cummings' method was used on pure Populus 'canadensis' in shelterbelts (5-23 years old) with occasional Salix viminalis; 65 poplar branches (diameter 0.3-12 cm.) and 35 willow branches (0.3-4.6 cm.) were sampled. Correlation coefficients of foliage weight with branch diameter of 0.89 and 0.86 were found for poplar and willow respectively. From this, calculation of the total foliage weight on sample trees, or on all trees on sample plots, by measuring the diameters of all first-order branches, is feasible, both as regards accuracy and the labour required.--Forestry Abs.

Spedding, C. R. W., and Large, R. V.
1957. a point-quadrat method for the description of pasture in terms of height and density. Brit. Grassland Soc. Jour. 12(4): 229-234, illus. [See POINT].

Sreenivasan, P. S.
1943. studies on the estimation of growth and yield of jowar by sampling. Indian Jour. Agr. Sci. 13(4): 399-412, illus.

A statistical analysis of the relation of plant characteristics of sorghum to yields, including methods of sampling.

Stoddart, L. A.
1935. range capacity determination. Ecology 16: 531-533.

A method is suggested for measuring accurately the stock carrying capacity of a western wheatgrass (Agropyron smithii) range in the mixed-grass prairie. It is based upon a simple count of the grazed and ungrazed stalks of wheatgrass within regularly located quadrats.

Willard, Donald R., and Smith, John B.
1935. variability in measurements of height and width of market garden plants. Amer. Soc. Agron. Jour. 27: 798-799.

Products of height X width more variable than either dimension alone, showing a tendency for tall plants to be wide. The two dimensions are not compensatory. The limit of nonsignificance is considered to be 3.3 X probable error.

L. FORAGE ANALYSIS

1. CHEMICAL ANALYSIS AND FORAGE VALUE

Baumgardt, B. R., Cason, J. L., and Markley, R. A.
1958. comparison of several laboratory methods as used in estimating the nutritive value of forages. (Abstract.) Jour. Anim. Sci. 17(4): 1205.

The efficacy of several _in vitro_ techniques for potential use in estimating the nutritive value of forages was studied with 11 forages (3 alfalfa and 8 grasses) of known digestibility as determined in conventional digestibility trials. Included in the studies: (1) Digestible Laboratory Nutrients, DLN (Agron. Jour. 47: 302, 1955) and (2) the prediction of TDN from anthrone carbohydrate digested _in vitro_ (Jour. Anim. Sci. 14: 1239, 1955). Also used as laboratory measures were cellulose and dry matter digestion as determined _in vitro_ by the artificial rumen technique. Values taken from the digestion trial data and used as reference guides included (1) TDN, (2) digestible calories per gram as well as digestion coefficients for (3) organic matter, (4) dry matter, (5) fiber, (6) cellulose, and (7) energy. Of the laboratory methods used, cellulose digestion appeared to be the most closely related to the _in vivo_ digestibility data. The correlation coefficients (ρ) of cellulose digestion _in vitro_ versus the several _in vivo_ values (as listed above) were: (1) 0.669*, (2) 0.726*, (3) 0.716*, (4) 0.811**, (5) -0.078, (6) 0.499, (7) 0.801**, respectively. Whereas relationship between _in vivo_ and _in vitro_ cellulose digestion was not significant when all forages were considered, the relationship was highly significant (ρ = 0.901**) for the grass hays. The relationship between TDN estimated from anthrone carbohydrate digested _in vitro_ and actual TDN was significant ($P < .05$). No significant relationship was found between DLN (_in vitro_) and TDN (_in vivo_).

Calder, A. B., and Voss, R. C.
1957. the sampling of hill soils and herbage, with particular reference to the determination of the trace elements. Consult. Com. Devlpmt. Spectrog. Work [England] Bul. 1, 52 pp.

The following factors contributing to variations in the trace-element content of soils and herbage from hill-land were studied: (a) variation in soil type and derivation at different sites and over small areas; (b) seasonal variation at the same site; (c) personal error; (d) variation in botanical composition; (e) contamination of samples; (f) analytical error. Trace-element contents of soils and herbage from 17 areas on two experimental farms are given. Coefficients of variation for Co- and Ni-contents of soil and herbage were relatively high (20-60 percent for herbage and up to 149 percent for soil samples).

The total analytical errors were negligible compared with the sampling errors. There was considerable variation within both Molinia caerulea and Nardus stricta. Variation between species was investigated for Calluna vulgaris, Trichophorum caespitosum, Molina caerulea, Juncus articulatus, Pteridium aquilinum, Nardus stricta and Festuca ovina. Co and Fe contents of herbage were positively correlated. The relationship between extractable soil Co and herbage Co is discussed. No suitable indicator species was found. Indications were that Calluna may accumulate Co and Trichophorum and Molinia reject it, even if available in the soil. A sampling scheme is outlined for advisory use.--Herb. Abs.

Cook, C. Wayne, Harris, Lorin E., and Stoddart, L. A.
1948. measuring the nutritive content of a foraging sheep's diet under range conditions. Jour. Anim. Sci. 7(2): 170-180, illus.

Need for an understanding of the nutrition problems on the western range is of paramount importance. Despite the importance of this problem, little is known as to the actual composition of the grazing animal's diet. The reasons for this lack of knowledge are many fold, including (a) difficulty of collecting representative samples of vegetation because of soil, site, and seasonal variations (b) difficulty of finding what species and portions of plants actually are consumed, and (c) difficulty in interpreting the nutritive content of the ingested forage. The method here presented for determining the nutritive content of the sheep's diet under range conditions is an entirely new approach to this problem and is based upon chemical analyses of the vegetation before being grazed as compared to chemical analyses after being grazed. Briefly, the method consists of collecting a predetermined number of plant units before grazing and a similar number after grazing. Each plant species is sampled both before and after grazing and each sample is weighed and chemically analyzed. The difference in weight and chemical composition between the before-grazing sample and the after-grazing sample serves as a measure of the nutrient content of the ingested forage. It was found from this study that sheep are highly selective in their diet and consume largely leaves and tender stems, rejecting the more fibrous parts of the plant. Consequently, a much better quality of forage actually makes up the diet than chemical analyses of bulk sample would indicate.

Du Toit, P. J., Louw, J. G., and Malan, A. I.
1940. a study of the mineral content and feeding value of natural pastures in the union of south africa (final report). Onderstepoort Jour. Vet. Sci. and Anim. Indus. 14: 123-327.

See Herb. Abs. 7, p. 5, 1937, for earlier reports in this series. The work noted in Herb. Rev. 8: 189-194, 1940, is given in detail

and includes an appendix in which tables are presented giving the origin, date of collection, chemical composition on a dry matter basis and an approximate description of individual pasture samples from eighteen areas in the Union.--Herb. Abs.

Francois, A.

1949. erreur commise dans le calcul de la valeur fourragère d'un aliment composé en fonction des erreurs de l'analyse chimique. [error in calculation of the forage value of a feed, as a function of the errors of chemical analysis.] Ann. Agron. [Paris] 19(3): 452-465.

The number of "forage units" per kg. of product is calculated as follows: (1) $FU=COM \times C_d \times C_t$ where FU=number of forage units per kg. of product, COM=crude organic matter in kg. per kg. of product, C_d=coefficient of digestibility, and C_t=coefficient of transformation in forage units. Let percent organic matter=COM; percent dry matter=DM; percent mineral matter=MM; then COM=DM-MM, from which the forage value, $y=(d-m) \times c \times t$, and the relative total error will be: (2)

$$\frac{\Delta y}{y} = \frac{\Delta s + \Delta m}{s-m} + \frac{\Delta c}{c} + \frac{\Delta t}{t} .$$

Interpretations and discussion are presented as well as tables showing coefficients of digestibility and "coefficients of transformation in forage units."

Grizzard, A. L.

1935. effects of soil type and soil treatments on the chemical composition of alfalfa plants. Amer. Soc. Agron. Jour. 27: 81-99. [See OTHER SITE RELATIONS]

Hellmers, Henry.

1940. a study of monthly variations in the nutritive value of several natural winter deer foods. Jour. Wildlife Mangt. 4: 315-325.

Samples of 8 species of woody plants browsed by deer were collected at monthly intervals and analyzed to detect variations in their composition. Marked differences were found, especially in protein, N-free extract, and crude fiber, all of which exhibited trends indicating reduction in nutritive value of the plants through the winter. A representative index to the nutritive value of winter browse may best be obtained by collecting material monthly and analyzing composite samples made by mixing the origin samples of each species in equal proportions. The samples should be collected at least in duplicate. This method tends to reduce errors that would be caused by fluctuations and seasonal trends. A few of the species analyzed compared favorably in chemical composition with bluegrass and timothy; most species were inferior to these grasses.--Biol. Abs.

Hundley, Louis R.

1959. available nutrients in selected deer-browse species growing on different soils. Jour. Wildlife Mangt. 23(1): 81-90.

In addition to comparison of results of proximate analyses run from September 1954 through October 1955 on five browse species growing on four study areas near Blacksburg, Virginia, minor elements determination for one month are reported. Present knowledge is insufficient to allow the use of proximate analyses as a basis for rating different plant species with regard to which provides the most nutritious browse for deer. Such analyses may, when accompanied by data regarding deer condition, be helpful in evaluating range conditions. --Biol. Abs.

Kivimae, A.

1959. chemical composition and digestibility of some grassland crops. Acta Agr. Scand. [Sweden] Sup. 5, 142 pp. [See INDICATOR METHODS IN DIGESTION STUDIES]

Lamb, K. P.

1957. quantitative microanalysis of leaf tissue for certain organic constituents with special reference to sampling error. New Zeal. Jour. Sci. and Technol. Ser. B. 38(9): 1009-1017.

Procedures are given for quantitative estimation of total nitrogen, amino nitrogen fractions, and soluble carbohydrates in microgram amounts in discs of leaf tissue weighing approximately 5 mg. (fresh) or 1 mg. (dry). Statistical aspects of sampling and analytical errors are considered.--Herb. Abs.

Lofgreen, G. P.

1951. the use of digestible energy in the evaluation of feeds. Jour. Anim. Sci. 10(2): 344-352.

A method is described by which it is possible to calculate the total digestible nutrient (TDN) value of feeds from the energy digestion coefficient. The conversion factor is calculated according to the formula:

$$F = \frac{OM}{100} \times \frac{100 + 1.25EE}{100}$$

where OM represents the percent organic matter in the feed and EE represents the percent ether extract in the organic matter. The TDN value of a feed is determined by multiplying the energy digestion coefficient by F. The TDN value determined by this method should be a more accurate measure of the energy value of a feed or ration than that determined by the conventional method.

McCullough, M. E.
1954. the use of t.d.n. in forage comparisons. Jour. Range Mangt. 7(3): 129-130, illus.

Calculated or determined TDN values of forages are not always accurate criteria of forage value. Using TDN intake as the dependent and animal production as the independent variables, multiple regressions were fitted and multiple correlation coefficients determined for forages of different qualities. They were: forages less than 65 percent digestibility (R)=0.408; 65-70 percent digestibility, 0.791; above 70 percent digestibility, 0.886.

Mott, N.
1957. die anwendung von futterwertzahlen bei der beurteilung von grünland-beständen. [the application of the fodder-value marking system for the estimation of grassland output.] Das Grünland [Bonn] 6(7): 53-56.

In applying the fodder-value marking system of Klapp (Herb. Abs. 24: 557) to manurial experiments on grassland, Jende (1955) coined the term 'quality-fodder yield' to express the effects of manuring on hay output. He obtained the 'quality-fodder yield' by multiplying the hay-yield by the fodder-value (Klapp system) of the hay. The author of the present paper suggests that 'yield-fodder-value-unit' (Ertrags-Futterwert-Einheit or EFE) is more accurate than Jende's term. The results of two manurial trials on grassland are used to compare hay yields, the Klapp marking system and EFE (all in both absolute and relative values). The author concludes that EFE is more accurate than the Klapp system which, in turn, is more accurate than hay-yield figures, for the true interpretation of the effect of manuring on the hay output of grassland.--Herb. Abs.

Neal, W. M.
1941. present knowledge of the nutritional value of grassland herbage. Amer. Soc. Agron. Jour. 33(7): 666-670.

A review article enumerating the known nutrients supplied by grassland herbage, with a consideration of methods of evaluation and factors affecting nutrient value.

Raymond, W. F.
1951. the problem of measuring the nutritive value of herbage. Brit. Grassland Soc. Jour. 6(3): 139-146.

(1) The importance of methods of measuring the feeding value of herbage, without recourse to digestibility experiments, is evident. The most promising approach seems in the use of relationships between the digestibility and chemical composition of herbage. (2) It is important then to know the possible errors there may be in the determination of

the digestibility and chemical composition of herbage. (3) Considerable differences in the chemical analysis of samples at different centers are likely, because of variations in the methods of drying, grinding and chemical analysis employed. (4) The digestibility of a given herbage feed may be modified by a number of factors, and should not be looked on as a constant for that feed. (5) In view of the variability shown under (3) and (4), the validity of regressions which do not recognize or correct for such variations can be questioned. It is recommended that a thorough study of the problem, especially in relation to the grass crop, should be made. (6) The limitations of present methods of converting digestibility data to net energy units are noted. (7) The complication that may be introduced by selective grazing may be approached via the chemical analysis of the feces. The same factors must be considered as in the case of herbage analyses.

Rigney, J. A., and Blaser, R. E.
1948. sampling alyce clover for chemical analyses. Biometrics 4(4): 234-239.

Duplicate determinations on each of two field samples from three replications of five fertilizer treatments on Alyce clover, Alysicarpus vaginalis, provided data for estimating variances due to plots, samples and chemical determination. These estimates were obtained for percentage of P, K, Ca and Mg in the clover hay. The accuracy of treatment means involving different numbers of plots, samples and determinations was examined. Relative costs for the three phases of the procedure were estimated and the cost per unit of information was computed for the various schemes under study. The optimum ratio of plots to samples to determination was calculated for a constant variance of the mean. In general, the relatively high cost and low variance of the laboratory determination require that this part of the technique be reduced to a minimum. The optimum ratio of total samples to total determination per treatment varied from 4 for Mg to 16 for K. Except for the unusually low plot-to-plot variance of Mg, the optimum number of samples per plot ranged from 2 for P to 4 for Ca.

Thomas, Brynmore, and Armstrong, D. G.
1952. the nutritive value of common heather (calluna vulgaris). I. the preparation of samples of calluna vulgaris for analytical purposes and for digestibility studies. Jour. Agr. Sci. [England] 42(4): 461-464.

An effort was made to devise a sampling procedure to obtain the portion of the heather plant which would be grazed by sheep. Methods including both hand clipping and mechanical means are discussed. No evidence of impairment of digestibility by oven drying for 24 to 48 hours at 38° C. was obtained.

Agerberg, L. S.
1957. bestämning av höprocent i vallförsök. [determination of "hay percentage" in grassland research.] Statens JördbrFörsök., Meddel. 87 24 pp.

At this farm in northern Sweden an exploratory study was made into the technique of sampling herbage, with special reference to rate of drying. This rate varies widely but under favorable circumstances water content can be reduced by up to 6-7 percent per hour, and the process is especially rapid during the first 30 minutes or so after mowing. Normally, the greatest degree of uniformity is achieved by sampling immediately after mowing. During the height of summer, air-drying of hay samples can be done satisfactorily, but with large samples, in poor weather or for autumn aftermath, air-drying must be supplemented by determination of dry-matter content, which should be obligatory whenever water content appreciably exceeds 15 percent. A method for sampling immediately after mowing is outlined, small plastic bags being used to prevent evaporation in the samples. After weighing the fresh samples, choice has to be made between determination of dry-matter content or some form of drying. In general a certain amount of pre-drying is to be recommended. The successful results achieved by artificial drying are noted.--Herb. Abs.

Bailey, P. H., Hughes, M., and McDonald, A. N. C.
1957. differential loss of dry matter in the laboratory grinding of dried herbage samples. Brit. Grassland Soc. Jour. 12(3): 157-165.

Comparison of results obtained on herbage samples freeze-dried and hot-air-dried during tests of commercial green-crop driers indicated apparent losses of crude protein and β-carotene in freeze-drying. Experiments on laboratory technique in drying, milling and analysing herbage samples showed a differential loss in conventional laboratory hammer mills biassed towards loss of high-protein particles. The differential loss was particularly marked for freeze-dried material, but was also shown to be significant for oven-dried material. There is a need for development of a laboratory mill to disintegrate samples without loss of milled material and without undue temperature rise when used for milling samples at the same rate as existing laboratory hammer mills.

Bartlett, M. S., and Greenhill, A. W.
1936. the relative importance of plot variation and of field and laboratory sampling errors in small plot pasture productivity experiments. Jour. Agr. Sci. [England] 26: 258-262.

An investigation of the relative importance in small plot pasture productivity experiments, of plot variations and of field and laboratory errors in sampling and subsampling for percentage dry matter and percentage nitrogen figures, revealed little advantage from duplicate sampling or subsampling in reducing the experimental error, which was due mainly to plot variation. The effect of sampling errors was of even less importance in the estimation of the actual yields of dry matter or of nitrogen.

Cooper, C. S., and others.
1957. the constituent differential method of estimating species composition in mixed hay. Agron. Jour. 1957 49(4): 190-193.

A method is presented for determining the species composition by weight of a two-component forage mixture when the two components contain different concentrations of the same constituent. Dry matter, calcium and crude protein were used to estimate the botanical composition of a clover/grass mixture. Measurements were made of the constituent concentrations of a large sample from each plot and of the species components from small samples taken at random from plots treated alike. The species composition of the large sample was then calculated using formulae. The method was more efficient than hand separation, at least when dry matter was measured.--From auth.

French, M. H.
1956. minimum size of experimental plots for the assessment of pasture yield. East African Agr. and Forestry Res. Organ. Rpt. 1956 [n.d.], 82-83. [Received Sept., 1957]

Trials at Muguga over a number of years, in which very large numbers of plots were sampled, indicate that the minimum plot size to give a 10 percent coefficient of variation in dry-matter herbage yields varies enormously according to luxuriance of growth. The minimum plot size is estimated to range from 16 to 755 sq. yd. for the same grass species. It is suggested that in arid and semi-arid areas, the minimum plot size should be 600 sq. yd.--Herb. Abs.

Isaacs, G. W., and Wiant, D. E.
1959. an averaging-type meter for measuring the moisture content of hay in the windrow. Mich. Agr. Expt. Sta. Quart. Bul. 41(3): 608-613, illus.

The moisture meter described measures the average electrical resistance at a large number of points in the windrow under test, and gives a quicker and less variable estimate of the average moisture-content of hay than the orthodox sampling technique.

McRostie, G. P., and Hamilton, R. I.
1927. the accurate determination of dry matter in forage crops. Amer. Soc. Agron. Jour. 19: 243-251.

1. The use of either green weights or the yield of field-cured hay as a basis of comparison in test plats is unreliable.

2. The practice of computing yields of comparative test plats on the basis of the loss of moisture of shrinkage samples dried to a constant weight, while reliable for the detection of reasonable large differences, still possesses an appreciable variable factor.

3. There is an appreciable and variable loss of dry matter in shrinkage samples held for air drying before being finally oven dried.

4. The immediate drying of shrinkage samples appears to offer the most accurate criterion for comparative tests.

Mitchell, G. E.
1957. methods of determining dry matter of fresh forages and silages. (Abstract) Jour. Anim. Sci. 16(4): 1089.

The following methods were used for determining the dry matter content of five lucerne/maize grain (ground, shelled) mixtures both before and after ensiling: toluene distillation, drying under vacuum at 95° C., drying in an oven at 105° C. and drying in an air-blast cabinet at 46° and 54° C. The silage mixtures were made from lucerne + 0, 5, 10, 20, and 40 percent ground, shelled maize. There were no significant differences between any of the methods of determination, except for the silages containing 10 percent maize meal, with which vacuum drying resulted in significantly lower dry-matter readings than drying in an air-blast at 46° or 54° C. The toluene method appeared to have no advantages over the other methods used. --Herb. Abs.

Raymond, W. F., and Harris, C. E.
1954. the laboratory drying of herbage and faeces, and dry matter losses possible during drying. Brit. Grassland Soc. Jour. 9(2): 119-130.

1. Preliminary studies on size of drying-tray, condition of herbage sample etc. indicated the probability of losses of dry matter during some forms of oven-drying.

2. On the basis of these results the Unitherm oven was designed.

3. Using the Unitherm oven, losses of five percent of the dry matter in herbage were found with warm-air drying, and over one percent by drying in another oven.

4. Using a radio-frequency oven, an average loss of one percent of the dry matter of herbage dried in the Unitherm oven, when full, was shown. This loss can be minimized by intelligent use of the oven.

5. Similar losses of dry matter have been shown during oven-drying of wet faeces.

6. A loss of 5-10 percent of the nitrogen in faeces on oven-drying at 100° C. has been found.

7. The possibility of losses during drying must be considered in relation to over-all experimental accuracy, and improvements made in dry matter determinations where necessary.

Savage, R. G.

1949. moisture determinations in the comparative testing of forage crops for hay yield. Sci. Agr. [Ottawa] 29(7): 305-329.

From 19 variety, strain or species tests in which one 1.5-lb. moisture sample had been taken per plot, the yield data were examined on a dry weight and a green weight basis, the comparison being based on the ranking of the varieties and on the statistical significance shown. Where tests did not include markedly different varieties or species, comparisons on a green weight basis gave essentially the same ranking and level of significance as did computation on a dry weight basis. It was concluded that for such tests several random moisture determinations would be sufficient to reduce green yields to a dry or hay weight basis for interyear comparisons. For tests involving more than one species or single species tests including rather markedly different varieties, fairly complete moisture sampling was found to be essential. Moisture sampling was done in three tests by taking duplicate 0.75-lb. and 1.5-lb. samples and triplicate 0.5-lb. samples from each plot. The smaller sized samples gave significantly different dry matter percentages and were more variable than the 1.5-lb. samples. In one test one 1.5-lb. sample per plot was as efficient as three 0.5-lb. samples. Use of more than one 1.5-lb. moisture sample per plot was found to be unjustified. In the three tests studied, sampling on the basis of one 1.5-lb. sample per plot in two random replicates and averaging the two determinations for each variety or treatment was essentially as reliable as sampling every plot in the tests.

Vries, P. de.

1957. verband tussen het drooggewicht, het versgewicht en de groeistadia van drie grassoorten en variëteiten. [the relationship between dry weight, green weight and growth stages of three species and varieties of grass.] Jaarb. Inst. biol. scheik. Onderz. 1957: 155-158, illus. [English summary.]

Three grasses were grown in pots in a glasshouse and harvested at intervals of about five days. They were an early Festuca rubra, a leafy and late pasture variety of Lolium perenne, and a less leafy, early, hay-type variety of L. perenne. In the relationships between green- and dry-weight, the data range along straight lines. The first line indicates a constant ratio between green- and dry-weight during the first period. The transition to the second line coincides with the time of emerging and occurs when the growing point is in the double-ridge stage. This second line indicates that the water content decreases with increasing dry weight. The time of emerging of Festuca rubra fell before the first harvesting date. The earlier the grass emerges, the shorter the period of constant water content. The second transition with the hay type Lolium perenne occurred when the mass of the ears appeared. The other plants did not reach this stage.--Herb. Abs.

Weihing, Ralph M.
1942. green and air-dry weights for determining hay yields of varieties of alfalfa. Amer. Soc. Agron. Jour. 34(10): 877-882.

The percentage dry matter in a number of varieties of alfalfa was determined in the green forage and in the forage air-dried under cover. The number of varieties or strains was five in one experiment and 55 in the other. There were 25 plots of each variety in the former and 2 in the latter. All varieties were grown in nursery plots. Data are reported on four cuttings; one in 1938 and three in 1939. The data show that some varieties and replications differ in percentage dry matter at the time of cutting and that the percentage dry matter in samples air-dried under cover for several weeks was nearly equal in all varieties. The percentage dry matter in green alfalfa evidently varies sufficiently between some varieties at the time of cutting to make forage yields based on green weights inaccurate. Green weights should be reduced by plot to oven-dryness, to an exact percentage of dry matter, or to air-dryness. Forage yields of alfalfa varieties based on samples or plots air-dried under cover are nearly as accurate as those based on oven-dry weights. For comparisons between cuttings or between years, air-dry forage yields should be reduced to a definite percentage of dry matter.--Biol. Abs.

Willey, L. A., and Dent, J. W.
1958. note on a method for sampling green crops for dry-matter determination. Empire Jour. Expt. Agr. 26(104): 379-381, illus.

Dry-matter determinations for crops such as kale, silage maize, and rape are often made on samples consisting of only 1-2 percent of the plot yield, thus involving considerable sampling error. A method is described in which all the green material from a given plot is passed through a mechanical chopper before sampling. The method is rapid and gives samples which are highly representative, even for those crops which show wide variations in the composition of different parts of the plant. The chopped sample material is also in a form very suitable for oven drying.--Herb. Abs.

M. SITE RELATIONS

1. EFFECTS OF COMPETITION

Aspinall, D., and Milthorpe, F. L.
1959. an analysis of competition between barley and white persicaria. I. the effects on growth. Ann. Appl. Biol. [London] 47(1): 156-172, illus.

Barley and white persicaria (Polygonum lapathifolium L.) were grown in pure and mixed populations of varying density in sand culture in a greenhouse. The leaf areas and dry weights of leaves, stems and roots were determined at intervals. During the phase of vegetative growth the addition of dry matter by barley was unaffected, although tillering was reduced, by competition from dense stands of white persicaria, whereas the growth of white persicaria was reduced by low densities of barley. The decline in leaf area and reduction in root growth of barley with the onset of flowering was accompanied by increased growth of white persicaria with the production of branches from the upper axillary buds. These flowered and set abundant seed. This behavior probably accounts for the persistence of this weed in arable rotations. The greater competitive ability of barley may be attributed to its larger embryo, giving much larger plants at emergence. The intrinsic relative growth rate of white persicaria is as high as, or higher than, that of barley and falls more slowly with time. This advantage is not sufficient to offset the initial differences in size while barley is vegetative. The larger embryo size of barley also determines the more intense competition that exists between plants of this species than between plants of white persicaria at similar densities and times from germination. With equal weights of produce per pot (or unit area) the intensity of competition within each species appears to be similar. It is emphasized that the course of growth with time, rather than weight-density relationships at given points of time, must be followed in order to understand the influence of density. Two functions of the relative growth rate with time are examined.--Auth. sum.

Donald, C. M.
1951. competition among pasture plants. I. intra-specific competition among annual pasture plants. Austral. Jour. Agr. Res. 2(4): [355]-376, illus.

A series of experiments was conducted to examine the influence of density, stage of growth, and fertility level on intra-specific competition among annual pasture plants. At sowing there is a linear relationship between density and yield (weight of embryos or embryo + endosperm per unit area). Competition is evident in dense populations shortly after germination and thereafter becomes operative progressively in populations of lower and lower density. Because of the

extreme reduction in growth rate in dense swards later in the season the high growth rate in sparse swards, the sparse sward tends to approach the more dense sward in its final yield. Final yield of dry matter is constant from moderate to high densities. There is no reduction in dry matter per unit area even in extremely dense swards. This maximum yield of dry matter for the environment is controlled by some factor of the environment. It is considered that nitrogen was the factor in two of the experiments here reported and light in the third. The significance of light in competition in pastures is discussed. Practical applications of these findings are discussed. --Auth. sum.

Donald, C. M.
1954. competition among pasture plants. II. the influence of density on flowering and seed production in annual pasture plants. Austral. Jour. Agr. Res. 5(4): [585]-597, illus.

Inflorescence and seed production were studied in swards of varying density of two annual Mediterranean pasture plants, Trifolium subterraneum L. and Lolium rigidum Gaud., each in pure culture. While the maximum level of dry matter production, achieved at moderate densities, was maintained at all higher densities, seed production showed a peak at moderate densities and thereafter a progressive decline. The greatest number of inflorescences was produced at densities exceeding those of peak seed production. Although the most widely spaced plants had the greatest numbers of inflorescences and seeds per plant, they had smaller seeds and fewer seeds per inflorescence than did substantially denser swards, apparently owing to intense intraplant (inter-inflorescence) competition at the widest spacings. It is suggested that the results can be explained in terms of the changing competitive relationships between and within the plants of the sward at the times of initiation of flower primordia, of floral development, and of seed production. Dense swards give most of the attributes needed in the use of these plants for grazing purposes; for seed multiplication swards of moderate densities give the highest yields of seed per unit area.--Auth. sum.

Hozumi, Kazuo, Asahira, Tadasi, and Kira, Tatuo.
1956. intraspecific competition among higher plants. VI. effect of some growth factors on the process of competition. Osaka Imp. Univ. Inst. Polytech. Jour. Ser. D. 7: 15-33.

Several garden varieties of vegetable crops were grown in pots or box frames under controlled conditions and the effects of soil moisture, soil depth and fertilizer supply upon the process of intraspecific competition were analyzed. The results in terms of average plant weight and average yield/unit area were first examined by the analysis of variance. The conclusions reached were as follows: (a) In all the experiments except one, the three factors exerted promotive effect on average plant weight. Interactions between them were

mostly significantly positive, whereas negative interaction prevailed between the factors and plant density. That is, the promotive effect of the factors on plant growth is reduced towards higher density. (b) The yield/area tended to be more or less constant regardless of the difference in density, although the three factors significantly increased the yield. (c) The responses of top-to-root ratio to the factors in root vegetables differed according to the kind of plants and factors. (d) Relative variation of plant weight was fairly constant on all plots in the turnip and radish experiment. Functional analyses of the experimental results proved that the competition-density effect formula, $wp^a=K$ or $w=Ks^a$, was always satisfied by average plant weight (w), plant density (p) and mean available space/plant ($s=1/p$). It was noted that the values of C-D index (a) was approximately constant in the same experiment regardless of the difference in treatments. In other words, the log w $\sim$ log p regressions were represented by a group of nearly parallel lines each corresponding to a particular combination of factor supply. This fact indicates that, contrary to the conclusion reached by the analysis of variance, there is no interaction between the effect of density and that of factor supply, when the former is interpreted by the C-D effect law. Further it was found that similar hyperbolic relations as the C-D effect equation always existed between w and the supply of a factor (f), or that $w=Kf^a$. Either accelerative or antagonistic interactions between the three factors became apparent when the experimental results were analyzed by this equation. Based on these results, the causes of the C-D effect and the law of constant final yield were discussed.--Auth. sum.

Hozumi, Kazuo, Kira, Tatuo, and Shinozaki, Kichiro.
1958. effect of light intensity and planting density on the growth of hibiscus moscheutos linn., with special reference to the interaction between two linear factors of growth. Physiol. and Ecol. [Japan] 8(1): 36-49. [In Japanese with English summary.]

Analysis was made on the growth of young rose mallow plants grown under 18 different conditions of light intensity and plant density. Seeds were sown on May 28, 1957, in china pots and after two weeks light intensity was regulated with lath frames. Average dry weight of each plant was recorded 28, 42, 49, 56, and 63 days after planting. Light intensity proved to be a linear factor. Mean available space was also a linear factor, whereas density may be called the reciprocal factor. Formulae are given for these various relations and related formulae on the same subject as well as their implications are discussed.

Iwaki, Hideo.
1958. the influence of density on the dry matter production of fagopyrum esculentum. Jap. Jour. Bot. 16(2): 210-226.

The influences of planting density on the dry matter production in a plant community were investigated on the basis of the field experiments with buckwheat in 1954 and 1955. Buckwheat plants were planted in regular square disposition and three different grades of spacing (5 cm., 10 cm., and 20 cm.) were employed. Sampling was made at intervals of 7 days for 2 months in each plot. The dry weights of leaves, stems, roots and reproductive organs and the total leaf area of the plants were measured. Variations of the net assimilation rate (NAR) with time were determined for each buckwheat stand. From the results, it was indicated that the NAR diminishes with increasing density of stand, at least in the earlier stages of development. The maximum assimilation of buckwheat leaves in densely planted stands was found to be lower than that in stands with lower densities. The C/F ratio, the ratio of the nonphotosynthetic systems (stems, roots and reproductive organs) to the photosynthetic system (leaves) was calculated for each plot. It was shown that the C/F ratio tends to become higher with increasing density in the earlier stages of growth, but in the later stages, no apparent correlation between C/F ratio and density was observed. From the analytical consideration with regard to the dry matter production in buckwheat stands, it was concluded that the higher values of NAR of the widely spaced stands are due mainly to (1) the higher relative light intensity in the plant community, (2) the higher rate of photosynthesis of the leaves and (3) the lower value of the C/F ratio than that of the closely spaced stand. The dry matter production of buckwheat plants was calculated indirectly from the daily assimilation and respiration, and the growth curve of the standing crop was constructed theoretically for each stand. The results of the calculation agreed well with those of the direct determination. The agreement of these values indicates that the growth curve of a plant community can be composed indirectly by the calculation of dry matter production and reproduction in the community.--Auth. sum.

Kira, Tatuo, Ogawa, Husato, Hozumi, Kazuo, and others.
1956. intraspecific competition among higher plants. V. supplementary notes on the c-d effect. Osaka Imp. Univ., Inst. Polytech. Jour. Ser. D. 7: 1-14.

Some new knowledge about the C-D effect law were presented. They are summarized as follows. Related formulations concerning the density effect in plant populations which appeared prior to our study were discussed. They are essentially the same in their mathematical representation as our C-D effect law, but more restricted in their scope and applicability. It was proved by several experiments that the C-D effect likewise held true not only in regularly dispersed populations but also in linearly planted and even in irregularly dispersed populations. The influence of the reduction of density during growth due to self-thinning upon the C-D effect was considered. Examples of the C-D effect in natural pure communities were presented with discussions as to the fundamental conditions necessary for the satisfaction of the law. It was found both experimentally and

theoretically that the effect of density on the yield of a certain part of plant body could also be described by the C-D effect equation, only if the growth of this particular part is prescribed by the law of allometry (relative growth). Values of the constant of relative growth calculated from various experimental results were comprised in a table and discussed.--Biol. Abs.

Knight, W. E., and Hollowell, E. A.
1959. the effect of stand density on physiological and morphological characteristics of crimson clover. Agron. Jour. 51(2): 73-76, illus.

In 1953-1957, crimson clover (Trifolium incarnatum) sown in the third week of September in each year produced earlier autumn and winter growth and greater forage yields when grown in dense stands than in thin stands. In November, 1955, clover plants spaced 0.75 in. apart were about 5 in. high, while those spaced 6 in. apart were about 0.7 in. high. In December, 1956, the 0.75 in. spacing produced 10,634 lb. green matter/acre, with a dry-matter content of 18.3 percent. The 6 in. spacing did not produce a similar yield until the following March. The numbers of seed heads per plant averaged 1.1 and 15.7 for the 0.75- and 6-in. spacings, respectively, and the numbers of stems per plant 1.5 and 18.7. Seasonal variation apparently affected height at maturity and number of florets per head as much as did stand density. Dense clover stands were damaged by Sclerotinia trifoliorum when the forage was not clipped. In 1956-1957, clipping controlled the disease during the growing season. Clipping reduced total dry-forage yields by an average of 609 lb./acre and seed yields by an average of 89 lb./acre. Forage from the clipped plots was of much higher quality than that from the unclipped plots.--Herb. Abs.

Koyama, Hirosi, and Kira, Tatuo.
1956. intraspecific competition among higher plants. VIII. frequency distribution of individual plant weight as affected by the interaction between plants. Osaka Imp. Univ., Inst. Polytech. Jour. Ser. D. 7: 73-94.

Attempts were made to estimate the nature of interaction between individuals in a population indirectly from the types and time trends of the frequency distribution of individual plant weight. Experimental evidence has shown that the types of weight distribution are approximately normal or Gaussian in the seed and young seedling stage, but that the mode of frequency curve is gradually biased from the central class to the left as plants grow. Sometimes the final distribution is represented by a kind of L-shaped frequency curve having the mode at the left end class. In many cases, the appearance of the final L-shaped distribution is promoted by increasing plant density. By assuming a simple mathematical model, it was shown that these particular types of frequency curve most probably belonged to the lognormal distribution, which is the natural outcome of the exponential nature

of fundamental growth process. The competitive interaction between plants was found to increase the variability of relative growth rate among individual plants and as the result to promote the appearance of L-shaped frequency curve. Close correlation between high density, competitive interaction, L-shape distribution of plant weight and high mortality of plants due to self-thinning was discussed based on both theoretical and experimental evidences. These results show that the frequency distribution of plant weight can serve as an indirect indicator of the processes of individual level going on within a population. Finally it was emphasized that the processes of populational level, as represented by the density effect laws concerning the average plant yield/population, are independent to the processes of individual level. This fact may be of great importance in asking for what is meant by the difference of levels in biological researches. --Auth. sum.

Kramer, H. H., and Davis, R. L.
1949. the effect of stand and moisture content on computed yields of alfalfa. Agron. Jour. 41(10): 470-473.

The relationship of stand and yield was determined for 30 varieties and strains of alfalfa established in 5-row plots and an additional 30 varieties and strains in single-row plots. Stand counts were made by dividing the rows into 6-in. units and determining the number of such units where there were no plants. The number of blank spaces was determined for each plot and expressed as a percentage of the total. In 1947, the first year after seeding, the correlation coefficient (ρ) of stand and yield and coefficient of regression (β) of yield on stand were 0.879 and 0.115, respectively. In 1948 ρ=0.801 and β=0.048. These lower β values in 1948 indicate that there has been a marked adjustment to thin stands. The apparent linear relationship of stand and yield indicates that the method of determining stand measures largely that portion of stand differences which contribute to yield differences. Moisture samples were taken for each plot over the 2-year period. Under the conditions encountered, sampling each harvested plot for percentage dry matter in order to determine yield at a specified dry matter content appeared to be unnecessary.

Piemeisel, Robert L.
1951. causes affecting change and rate of change in a vegetation of annuals in idaho. Ecology 32(1): 53-72.

The communities that compose the greatest part of the vegetation of annuals on lands formerly occupied by sagebrush-grass are Russian thistle, mustards, and downy chess. The three communities have an optimum arrangement in appearance-time and in space covered. This optimum arrangement is a potential that is realized on a cleared area if there is sufficient control of destruction of plants and is open to repeated demonstration and measurement. In this optimum

rate of change Russian thistle dominates the greatest space the first two years; mustards, the third and fourth and downy chess from the fifth year on. Within each of the communities there is a development best observed in one of downy chess and in an island somewhat removed from an established stand. This starts as a solitaire, a beginning age; then a cluster of a few individuals, the young age; then a dense stand, the mature age; and finally a very dense stand, the degenerate age. These age-groups are distinguishable in an island in color, height, and maturity (head emergence) as well as by density. The changes from one community to another and the processes that take place within a community are determined by plant characteristics and proceed in spite of differences in weather in years of above or below average precipitation. Sparse stands mature and produce seed in years with precipitation below average and excessively crowded stands dry prematurely in years of above average precipitation. Spacing of individuals within groups, the degree of crowding, determines distribution of the limited soil moisture supply of a unit area among individuals. The soil moisture supply of the individual is determined by the amount put into the soil (precipitation) and by number of individuals (density) and of these two, precipitation varies by far the less. Repeated observations and measurements and experiments may be made on these communities because of their short life-span and rapid rate of change.

Van Rensburg, H. J.
1942. a comparison of quadrat results and phenological data in a series of highveld grassland grazing experiments subjected to different treatments over a period of six years. So. African Jour. Sci. 38: 186-197.

The fertilizer treatments for the various plots are described, and the quadrat results on each plot are discussed in detail. In most instances generalizations could not be made and no conclusions could be drawn, but results clearly indicate that the change in certain species is most consistent according to the treatments given. It is, for example, clearly shown that in most cases the small tufted and runner grasses cannot compete for light with the tall bunch grasses, and that under conditions of protection these species are smothered and suffer severely, while the larger bunch grasses develop to their maximum capacity.

Shinozaki, Kichiro, and Kira, Tatuo.
1956. intraspecific competition among higher plants. VII. logistic theory of the C-D effect. Osaka Imp. Univ., Inst. Polytech. Jour. Ser. D. 7: 35-72.

In order to give reasonable interpretations to the competition-density effect law empirically suggested in preceding reports, a theory was proposed based on the following logistic model: (a) The growth of a plant in dry weight (w) is described by the general logistic curve,

$$\frac{1dw}{wdt} = \lambda(t)\left(1 - \frac{w}{W(t)}\right);$$

(b) The coefficient of growth (λ) in the logistic equation is independent to plant density (p); (c) Final yield/unit area (Y=Wp) is constant irrespective of the difference in plant density (the law of constant final yield); and (d) All the plants are seeded simultaneously at t=0, when the average seed weight is constant and independent to density (the initial condition). From these basic assumptions it was concluded that the w~p relation for any given time could be represented by the equation, $\frac{1}{w} = Ap+B$,

in which A and B are the known functions of time (t). This equation was called the reciprocal equation of the C-D effect. The C-D effect equation hitherto used, $wp^a=K$ (a and K are both constants determined by t), or the power equation, was considered to be nothing but a crude approximation of the reciprocal equation, but it has certain advantages for practical purposes. The fitness of the reciprocal equation to a number of experimental results proved satisfactory. It was only when the so-called cooperation occurred that the equation failed to fit the experimental data. The cooperation is to be considered as a kind of abnormal growth from the standpoint of the logistic theory. Probable causes of this phenomenon were discussed. The method for calculating the characteristic quantities of growth such as W(t), λ(t), etc. from the observed values of A and B was presented. Quantitative analysis of growth curves of plant upon logistic basis thus became possible. It was proved that the growth curve must be the general logistic curve, provided the reciprocal equation, associated with the law of constant final yield, was always recognized as the experimental facts. In other words, the growth process of higher plant has the fundamental property that it can be approximated at any given moment by the simple logistic equation. Necessary modifications to the law of constant final yield at extremely high density ($p \to \infty$) was considered as related to the autoregulation of density of self-thinning. Also a reasonable treatment of the law at another extreme (p=0) was presented. Putting s=1/p in the reciprocal equation, the resulting following equation represents the effect of mean available space in plant growth. $\frac{1}{w} = \frac{A}{s} + B.$

This is a new alternative for the well-known Mitscherlich's formula. Although the two formulae closely resemble each other, the latter was proved inadequate so far as the space factor is concerned.--Auth. sum.

Wit, C. T. de, and Ennik, G. C.
1958. over concurrentie. [on competition.] [Wageningen] Inst. v. Biol. en Scheik. undig Onderzoek van Landbgew., Jaarb. 1958: 59-73. [In Dutch with English summary.]

The statistical aspects of experiments on plant competition are described for plants which do, and those which do not, derive benefit

from the presence of another species. It is shown that it is much simpler to carry out 1-year experiments, using varying proportions of each species in the experimental population, than to follow the change in composition of a mixture over several years, as the former are not complicated by changes in growing conditions from year to year. Experiments to determine the effect on yield of the distance between rows of crops can be treated as experiments on competition between rows with plants and rows without plants. A linear relationship can be demonstrated between the row spacing and the reciprocal of the yield.--Herb. Abs.

Alekseenko, L. N.
1958. [structure of a perennial herbage sward in relation to yield.] Vseso Juzn. Akad. Selsk-Khoz. Nauk im. V. I. Lenina Dok. (Lenin Acad. Agr. Sci. Proc.) 23(6): 14-18. [In Russian.]

Sward structure has been studied hitherto chiefly in the period of the sward's maximal development. This work is concerned with changes in sward structure in pure and mixed sowings during the whole vegetative growth. The sward in this study consisted of Phleum pratense, Festuca pratensis, Dactylis glomerata, Trifolium pratense and Medicago sativa, these species being typical for swards in the northwest USSR. The plants were sown in pure plots and in six mixed cultures each comprising one legume and one grass. Sward structure was determined by cutting herbage samples from the plots on areas 15 $\times$ 15 cm. at 10 cm. horizons, from ground level upwards. The samples from each horizon were divided into leaves, stems and flowers, the volume and weight of each group being determined; in addition leaf area was measured. Replication was 4- or 6-fold. In the first year sampling was done in mid-August when the grass was 35-45 cm. high, at the tillering stage, and Ph. pratense had some flower initials. The legumes at this date were 50-60 cm. high, at the budding stage. The second sampling was done a month later. Apart from the general increase in volume, there was little difference in the results from the two dates of sampling. In pure sowings, the greater part of the vegetative mass of grasses was concentrated nearer to the soil surface than in pure sowings of legumes. On the average for all the grasses, 44.2 percent of the total mass was in the 0-10 cm. horizon, while for the legumes the amount was 23.5 percent. In all the mixtures, the above-ground mass was distributed more evenly in the different horizons and this ensures better illumination within the herbage stand and better utilization of CO_2. The sward was analyzed four times in the second year, viz. at tillering/shooting; earing/budding; flowering; and in the aftermath. The data of all the analyses are recorded in charts and tables; it is shown, for example, that in the second year leaf area of red clover at the flowering stage in pure sowing was 9.68 sq. m. per sq. m. soil; for red clover + cocksfoot, 23.76; for lucerne in pure sowing, 17.5; for lucerne + cocksfoot, 18.25. Mixtures produced a greater mass of herbage than did pure sowings. In the author's experiments leaf area was closely related to plant species and stage of development and was greater in mixed swards than in pure sowings. The leaf's assimilating powers determine ultimate yields, and plants in pure sowings show somewhat greater photosynthetic activity than in mixtures. For example, on 5 July the photosynthetic intensity of clover in pure sowing was 10.5 mg. CO_2 per hour per sq. dm., but in mixed sowing it was 7.1 mg. However, the total for the mixture was greater because of the greater leaf area in the mixed stand. There is need for a grazing system which will ensure an even distribution of herbage in each horizon of the stand.

Billings, W. D.
1941. quantitative correlations between vegetational changes and soil development. Ecology 22(4): 448-456, illus.

The use of quantitative methods in correlating plant succession and soil development is described, and the existing literature reviewed. Linear and curvilinear regression are applied to soil and vegetation data from successional and climax examples in the Piedmont and mountain regions of North Carolina. Using the equation, $E = \bar{y} + (\Sigma xy / \Sigma x^2)(X - \bar{x})$, a highly significant coefficient of 0.0212 is shown for the regression of percent organic matter in the A_1 horizon on the age of shortleaf pine (P. echinata) stands. Highly significant coefficients are also presented for the regression of water-holding capacity, volume-weight, and moisture equivalent of the A_1 horizon on percent organic matter in the same soil under shortleaf pine stands. Highly significant regression coefficients showing the relationship of hardwood reproduction under pine to certain soil factors are also presented. The curvilinear relationship between volume-weight and percent organic matter under conditions resulting in high values for the latter factor in a virgin hemlock (Tsuga canadensis) stand are brought out by the use of the second degree polynomial equation $Y = a + bX + cX^2$ yielding in this case $Y = .6969 - .0121X_1 + .00006X_2$ where Y is equal to the volume-weight.

Boer, T. A. de, and Ferrari, T. J.
1957. bodemvruchtbaarheid, vegetatie-karteringseenheid en opbrengst van grasland in een zandgebied (geldersc vallei). [soil fertility, vegetation-survey units and production on old permanent pastures in a sandy region (gelders valley).] [Netherlands] Div. van den Landbouw, Verslag. van Landbouwk. Onderzock. 62.15 [n.d.], 23 pp. [In Dutch with English summary.]

The relation between botanical composition on the one hand and soil fertility, water supply and yield on the other was studied by means of estimates made in 237 plots of 100 sq. m. in a sandy region. The accuracy of the estimates was controlled by the measurement of yield in 5-sq. m. cages on 50 plots. Botanical composition is denoted by means of vegetation survey units (abbr. V.S.U.), which form a scale indicative of the quality of the grassland and of its utilization. For example 0- indicates a sward containing > 75 percent good grasses of which > 50 percent is Lolium perenne, while at the other end of the scale 8- denotes a sward having < 35 percent of good grasses. Of these units there are variants which indicate moisture conditions, so that, for example, -1 denoted the presence of > 30 percent of species which are indicators of dry conditions. Correlations were established between these V.S.U.'s and the grade of quality and grass yield; pH-KCL; K-status; P-status; Mg-status; N-status; ground-water level and water-holding capacity; for details of which the reader is referred to the tables and summary. The water supply of the region surveyed is the main factor determining the yield and quality of its grassland.

Brougham, R. W.

1955. a study in rate of pasture growth. Austral. Jour. Agr. Res. 6(6): [804]-812, illus.

The growth curve of a pasture consisting of short-rotation ryegrass, red clover, and white clover was determined by measuring dry matter yields at intervals over a 9-week period in the spring of 1953. To determine the effects of temporary weather variations on growth, the experiment was replicated in time as well as space. The experimental technique is described. The curves of growth for ryegrass and total herbage were sigmoid. In the second phase of growth of approximately 5 weeks when rate of growth was constant, the daily increment in total herbage approached 150 lb. dry matter per acre. Total herbage yields were separated into two parts to give a growth effect for a constant (mean) climate and an irregular weather effect. This latter separation showed agreement with fluctuations in temperature and rainfall. The results are discussed in terms of pasture management practices, and the possibilities of growth rate studies for future pasture experimentation are considered.--Auth. sum.

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1959. the effects of season and weather on the growth rate of a ryegrass and clover pasture. New Zeal. Jour. Agr. Res. 2(2): 283-296.

An experiment is described in which the effects of seasonal climate and of temporary (weekly) weather variations on the growth rate of a pasture of short-rotation ryegrass and white clover were determined. The technique of measurement included replication in time as well as space. Statistical analyses showed significant positive correlations between seasonal trends in growth rate and light and temperature. Positive correlations were also obtained for the weekly fluctuations in growth rate attributable to weather factors. The pasture was irrigated during the summer and early autumn so that water was at all times adequate for growth. The average daily growth rate of the pasture ranged from 10 lb. of dry matter (d.m.) per acre in the winter to 120 lb. per acre in early summer. The weekly fluctuations in growth rate attributable to weather factors were as large as ± 50 percent of the weekly growth rate. The potential annual yield of d.m. obtainable from this pasture type growing in this locality, was estimated as 22,000 lb. per acre.--Auth. sum.

Cox, C. P., Hosking, Zena D., and Line, C.

1958. within-field changes in herbage composition and soil moisture. Brit. Grassland Soc. Jour. 13(3): 187-195, illus.

In the results from a previously reported uniformity trial on pasture evaluation, there appeared to be systematic areal changes in the crude fiber and crude protein percentages of the herbage. These trends have been illustrated by the calculation of quadratic contours and the

possible relationships of the changes to local soil differences, moisture percentages and copse shelter effects have been investigated. --From auth. sum.

Emmett, H. E. G., and Ashby, Eric.
1934. some observations on the relation between the hydrogen-ion concentration of the soil and plant distribution. Ann. Bot. [London] 48(192): 869-876.

Before conclusions can be drawn as to the influence of pH upon the distribution of a species it is necessary to obtain data regarding the distribution of pH by random sampling independently of presence or absence of the species. For example, data for frequency of Pteridium aquilinum and Vaccinium myrtillus showed well-defined modes at pH 5.6, but random soil samples showed a mode at the same pH. Statistical examination of the data reveals no evidence of correlation between distribution and pH between 4.7 and 6.2.--Biol. Abs.

Evanko, Anthony B., and Peterson, Roald A.
1955. comparisons of protected and grazed mountain rangelands in southwestern montana. Ecology 36(1): 71-82.

Various characteristics of vegetation and water absorption by soils were measured on selected areas in southwestern Montana to determine effects of grazing and protection. Composition of vegetation within and outside exclosures varied considerably among study areas even though they were within a 1-1/2 mile radius of each other. Total cover provided by grasses was greater on the protected than on grazed portions. Poa secunda was the only grass species persistently most abundant on the grazed parts of the areas. Forbs and shrubs were most common on the grazed portions, small but consistent differences existed, and no species appeared to have indicator value. A compositional pattern could not be defined for the type because of variability among areas. Leaf heights, basal area per clump, and herbage yield per plant and per square centimeter for the main forage species (Festuca idahoensis, Agropyron spicatum, A. dasystachum, and Calamagrostis montanensis) were greatest on the protected portions. These characteristics were very similar among areas for Festuca idahoensis and Agropyron spicatum especially. Calculated herbage yield of most common forage species, soil surface litter, and rate of water absorption by the soil were usually substantially less on the grazed portions of the areas. These items also varied considerably between areas within treatments. Under light grazing use, amount and kind of cover and plant frequency did not reflect the grazing treatment when compared with a similar protected area. Height, basal area, yield per clump, and yield per sq.-cm. measurements differed less in this comparison than in those where protected and more heavily grazed areas were compared. Leaf height, plant area, and yield per clump and unit of plant area of individuals of important forage species appear to furnish more usable and reliable criteria for

evaluating range condition of this mountain bunchgrass type than do estimates of cover. Exclosures, strategically located may provide a standard for evaluating in a relatively simple manner the degree to which grazing treatment has affected certain characters, especially those associated with plant vigor.

Grizzard, A. L.
1935. effects of soil type and soil treatments on the chemical composition of alfalfa plants. Amer. Soc. Agron. Jour. 27: 81-99.

The effect of various fertilizer treatments on the partial composition of Medicago cut in the bud stage, and the first and second cutting for hay at the one-half bloom stage, is recorded for different soil types. Correlations are drawn between soil type and nutritional disorders in cattle, the heavy and medium textured soils producing hays with unfavorable nutritive balance. From a comparative study of the random and systematic methods of sampling for chemical analysis, it is concluded that the latter method has no advantage over the former. --Herb. Abs.

Hopkins, Harold H., Albertson, F. W., and Riegel, D. A.
1952. ecology of grassland utilization in a mixed prairie. Kans. Acad. Sci. Trans. 55(4): 395-418, illus.

The correlations between rainfall, soil moisture, growth, yield, moisture content, protein content, utilization of vegetation and the yield of beef obtained on the college pasture near Hays, Kansas, from 1947 through 1950 are presented. The role of soil moisture is paramount in a successful livestock program in this mixed prairie area.

Hopkins, J. W.
1935. weather and wheat yield in western canada. I. influence of rainfall and temperature during the growing season on plot yields. Canad. Jour. Res. 12(3): 306-334, illus.

A statistical study of plot yields recorded at several agricultural experiment stations in central and southern Saskatchewan and Alberta has demonstrated a significant correlation between yield and amount and distribution of seasonal rainfall. On the whole, above-average rainfall is associated with higher yield, but the result of a given increment of rain at different times partly depends on soil conditions. On fertile soil, rainfall prior to harvesting results in a reduction of yield, probably owing to lodging. The maximum influence of precipitation upon yield appears to be exerted during June. The average summer rainfall sequence is very similar in each of the above four districts. There is a moderate degree of correlation between amounts of rain recorded in different districts during the same season, but simultaneous occurrence of extremely wet or dry seasons

over the whole area seems infrequent. Temperature conditions during the growing season seem to be secondary to rainfall in influencing yield. Above-average temperature is beneficial at time of sowing, detrimental during midsummer and again beneficial prior to ripening, but as in the case of rainfall, the effect produced is influenced by soil conditions. No consistent relation is evident between either rainfall or temperature and the relative yield of early and late maturing varieties.--Auth. abs.

Ishimoto, Toshio Tom.
1958. systematic considerations as influenced by certain ecological factors related to plant distribution on serpentine soil in central california. Diss. Abs. 19(4): 650.

van Itallie, T. B.
1937. de invloed van verschillende factoren (maaitijd, botanische samenstelling, bemesting en grondsoort) op de chemische samenstelling van gras. [the influence of different factors (time of mowing, botanical composition, manurial treatment and soil type) on the chemical composition of grass.] Landbouwk. Tijdschr. [The Hague] 49: 155-170. [English summary, pp. 168-169.]

In the Netherlands the chemical composition of grass is as a rule much more affected by the stage of growth and by botanical composition than by manurial treatment and soil type. This is illustrated by studies of herbage sampled at different dates from pure cultures and normal grassland respectively. The relation of lime content to percentage of clovers and weeds after three or four years of different manurial treatment is shown. In discussing the influence of manurial treatment, a distinction is made between direct effect (increasing uptake of N, P and K, etc.) and indirect effect (changes in botanical composition). The use of K and P as a rule causes changes in the composition of the grass, but, at least in the case of P, changes in subsequent years due to cutting at different stages of growth may be much greater than those caused by manuring. The influences of Ca, Mg and Na are briefly mentioned. The improvement of natural grassland on peat soil with farmyard manure followed by artificial fertilizers produces very great changes in chemical composition, due to changes in botanical composition.--From auth. sum.

Jowett, G. H., and Scurfield, G.
1949. a statistical investigation into the distribution of holcus mollis l. and deschampsia flexuosa (l.) trin. Jour. Ecol. [London] 37(1): 68-81, illus.

Deschampsia-dominated soils within woodlands investigated have a pH less than 3.25, and Holcus-dominated soils, a pH above 3.25. The succession from Deschampsia-dominated soil to Holcus-dominated soil

involves changes from a mor type toward the mull type, and a change in moisture content from a more xeric to a mesic type.

Jowett, G. H., and Scurfield, G.
1952. statistical investigations into the success of holcus mollis l. and deschampsia flexuosa (l.) trin. Jour. Ecol. [London] 40(2): 393-404.

Estimates of the success (determined as yields fresh and dry weight and by number of shoots per quadrat) of the two species in different woodlands and under different types of tree cover within a woodland are correlated with the edaphic variables pH, percent moisture and percent organic content of the soils at the sampled points. Increase in pH is associated with an increase in yield of fresh weight of Holcus mollis and a decrease in that of Deschampsia flexuosa. Two sampling designs are employed, the relative merits of which are critically examined; a transect design with the sampling points at the equally-spaced intersection of a carefully mapped grid is recommended.

Kayama, R., and Mizuno, T.
1959. studies on estimation of grazing capacity and utility of mountainous grassland. I-II Jap. Jour. Zootech. Sci. 30(4): 231-241, illus. [In Japanese.]

I. Effect of slope elevation on the chemical composition of topsoil and the yield of native plants; II. Relation of slope elevation to the physical character of topsoil and estimation of the yield of native plants.

Kershaw, K. A.
1958. an investigation of the structure of a grassland community. 1. the pattern of agrostis tenuis. Jour. Ecol. [London] 46(3): 571-592.

This is the first of a series of papers in which the patterns of four species in a grassland community are discussed in relation to their environment and to each other. The area studied was an upland Festuca/Agrostis grassland that had been reseeded over a number of years and was reverting to its original state. There is support for the view that the nutritional level in the soil is a limiting factor in the distribution and relative abundance of A. tenuis and F. ovina. --Herb. Abs.

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1959. an investigation of the structure of a grassland community. 2. the pattern of dactylis glomerata, lolium perenne and trifolium repens. 3. discussion and conclusions. Jour. Ecol. [London] 47(1): 31-53.

The importance of replicated samples is discussed in relation to the interpretation of pattern analyses. A pattern of low intensity, but repeated occurrence in a comparable series of analyses, can thus be established as a characteristic of the vegetation under investigation, and not a chance heterogeneity. The causal factors of pattern in vegetation can be grouped under three headings: (a) morphological pattern; (b) pattern resulting from competition between two or more individuals (sociological pattern) and (c) pattern resulting from variation in topography, soil depth, water availability, etc. (physiographic pattern). It is suggested that cyclic phases in vegetation are a widespread phenomenon, especially in rhizomatous species. The structure of "climax" vegetation is discussed in relation to the "amount," type and intensity of pattern present. It is concluded that stable vegetation will have a minimum number of scales of pattern present, and in a climax community, with absolute homogeneity of the environment, the pattern present would be solely (a). The existence of such an idealized vegetation is doubtful and it is likely that, to some extent, (c) will be present; (b) will be absent, such pattern being characteristic of seral phases leading to a stable vegetation type.--Herb. Abs.

Kershaw, K. A., and Tallis, J. H.
1958. pattern in a high-level juncus squarrosus community. Jour. Ecol. [London] 46(3): 739-748.

The structure of a Festuca ovina - Juncus squarrosus association is examined and a series of mosaic patches is described. The mosaic patches are visually indistinguishable, consisting of areas where the density, vigor, and pattern of J. squarrosus varies, expressing the different times of colonization. The mosaic patches are probably maintained by varying depths and water-holding capacities of the soil and show a general trend of reduction of pattern with their increasing development.--Biol. Abs.

Lister, P. B., and Schumacher, F. X.
1937. the influence of rainfall upon tuft area and height growth of three semidesert range grasses in southern arizona. Jour. Agr. Res. 54: 109-121.

The effect of variation in precipitation distribution during a 15-month period on the annual density change and height growth of the three forage grasses [three-awn grass (Aristida species), black grama (Bouteloua eriopoda), and Rothrock grama (B. rothrockii)], within the growing season of the current year, was determined by statistical analysis. The method used consisted in describing the observed monthly precipitation during each 15-month period ending with August for each station and year, by orthogonal polynomials of degree 8; the coefficients of these were then used as independent variables in six multiple-correlation analyses, the dependent variables of which were (1) the annual density change, and (2) the height growth of flower

stalks of each of the three grasses according to station and year. All the correlations are highly significant. Graphic expressions of the average effect of an added inch of precipitation per month indicate, in the case of the two grama grasses, that the most beneficial precipitation distribution from normal for both density change and height growth consists of relatively dry winters sandwiched between relatively wet autumns and springs. Three-awn grass seems admirably adapted to the variation in precipitation distribution characteristic of the area studied in that either positive or negative departure from normal seasonal precipitation benefits, in general, either density change or height growth, although not both at once.--Auth. sum.

Lush, R. H.
1935. five years results on monthly clipping of pastures. Jour. Dairy Sci. 18: 295-299.

The experiments were carried out in the growing seasons 1930-1934. The prevailing, early vegetation consisted of _Trifolium repens_, and/or _T. procumbens_, _Lolium_ spp., _Phalaris_ spp., and _Avena_. This herbage was replaced later in the seasons by _Paspalum dilatatum_, _Cynodon dactylon_ and a small amount of _Axonopus compressus_. The areas were cut each year during the first week of March and at 30-day intervals throughout the growing season. A tabulation is given of rainfall, yield, chemical analyses and nutritive values for the different cuttings. The following points are emphasized: (a) Yields were at a maximum in April and August; (b) Early spring grass contains nearly twice as much crude protein as that cut in September. In view of chemical changes involved during the advancing season, the computed total digestible nutrients per 100 lb. of grass tends to rise to 15 in midsummer and then gradually declines; (c) There is considerable uniformity in analyses of grass clipped on the same date irrespective of botanical composition. Rainfall, maximum and minimum temperatures are discussed in relation to growth rate, composition and yield of herbage.

Metzger, W. H.
1935. the relation of varying rainfall to soil heterogeneity as measured by crop production. Amer. Soc. Agron. Jour. 27: 274-278.

The crops grown on plots each 1/20-acre in size during a period of 9 years were corn, oats, wheat, _Medicago_, and Atlas sorgho. It is shown that there is inverse relationship between the rainfall and soil heterogeneity as reflected in the extent of variability of the crop yields from uniformly cropped field plots receiving no fertilizer treatments. The necessity for smaller plots and more replications in many field experiments is indicated by this relationship, and the value of a uniform cropping period as a means of establishing definite variability in the crop producing ability of a group of experimental plots would appear to be limited.

Pase, Charles P.
1958. herbage production and composition under immature ponderosa pine stands in the black hills. Jour. Range Mangt. 11(5): 238-243, illus.

A logarithmic relationship was found between herbage production in 1956 and percent pine crown cover, basal area, and pine litter. Total herbage ranged from 40 pounds/acre air-dry under a 70 percent crown canopy to 2160 pounds on clearcut areas. Grasses and sedges produced 66 percent of the herbage under relatively open stands (0-19 percent crown cover). Grasses and sedges showed the greatest increase in pounds/acre as crown cover decreased. Kentucky bluegrass (Poa pratensis), the heaviest producer under open stands and in clear-cut areas, decreased sharply as crown canopy increased, as did little bluestem (Andropogon scoparius), prairie dropseed (Sporobolus heterolepis), and fuzzyspike wildrye (Elymus innovatus). Roughleaf ricegrass (Oryzopsis asperifolia) and sedges (Carex spp., largely C. pennsylvanica) increased in relative importance but decreased in pounds/acre. Bearberry (Arctostaphylos uva-ursi), common juniper (Juniperus communis), and snowberry (Symphoricarpos occidentalis) were the most plentiful shrubs. Bearberry produced the greatest amount of herbage under moderately open stands. Snowberry, while not a heavy producer, was persistent under dense pine canopies.--Biol. Abs.

_______, and Hurd, R. M.
1957. understory vegetation as related to basal area, crown cover and litter produced by immature ponderosa pine stands in the black hills. Soc. Amer. Foresters Proc. 1957: 156-158.

Production of grasses, broad-leaved herbs and shrubs all increased as the basal area and crown density of the pine stand and lb. litter/acre decreased. As the basal area of the pine stand decreased from 200 sq. ft./acre to zero, grass production increased from 13 to 1330 lb./acre; production of broad-leaved herbs increased from 2 to 210 lb./acre; and shrub production increased from 7 to 120 lb./acre.--Herb. Abs.

Rayson, Patricia.
1957. dark island heath (ninety-mile plain, south australia). 2. the effects of microtopography on climate, soils, and vegetation. Austral. Jour. Bot. 5(1): 86-102, illus.

By the method of positive interspecific correlation of the data, four plant communities were distinguishable in the heath vegetation. Three of these were delimited by differences in micro-habitat dependent on the essentially unidirectional rain-bearing winds and on dune topography. They were located on eastern dune slopes, western dune slopes, the sandplain, and the fourth was found in scattered sites. Delimitation of the habitats and communities was not clear-cut. The concept of a varying continuum was found to be applicable to the vegetation studied.

Rogler, George A., and Haas, Howard J.
1947. range production as related to soil moisture and precipitation on the northern great plains. Amer. Soc. Agron. Jour. 39(5): 378-389, illus.

This study was conducted to determine if fall soil moisture in rangeland could be used to predict the following seasons forage yields and cattle gains. Eighteen years' data were available for forage yields and 19 years' for cattle gains. The relationship of April-July precipitation alone and together with the preceding fall soil moisture, and current season forage yields and cattle gains was also determined. Highly significant coefficients of 0.72 and 0.74 were obtained for the correlation of forage yields and available fall soil moisture in the surface 3 ft. and 6 ft., respectively. The correlation coefficients for cattle gains and fall soil moisture in the surface 3 ft. and 6 ft. were 0.52 (significant) and 0.64 (highly significant), respectively. April-July precipitation showed approximately the same correlation to yields and gains as fall soil moisture in the surface 6 ft. When April-July precipitation and soil moisture were added together, the correlation with yields and gains was higher. The data indicate that below average yields and gains can be predicted fairly accurately when the soil is dry the preceding fall. With increasing quantities of moist soil, increasingly higher yields and gains can be expected on the average, but prediction is less accurate.

Sears, P. D.
1956. the effect of the grazing animal on pasture. Seventh Internatl. Grassland Cong. Proc. 1956: 92-101.

Aspects discussed include animal treading, defoliation by grazing stock, and manuring. "A natural corollary to the appreciation of grazing animal effects is the necessity to incorporate such effects into pasture trials, or to allow for the absence of such effects, in the interpretation of the experimental results." Of possible methods for pasture management trials, limitations are found in all but the system of using self-contained blocks for each replicate, in which case the true ecosystem of soil, plant and animal is complete for that replicate. With this system treatment differences are valid for direct application to practice.

Shepherd, W. O., Dillard, E. U., and Lucas, H. L.
1951. grazing and fire influences in pond pine forests. N. C. Agr. Expt. Sta. Tech. Bul. 97, 56 pp., illus.

Responses of pine reproduction and other understory vegetation to grazing and wildfire, and cattle performance under two intensities of grazing, were studied in logged and unlogged pond pine (Pinus rigida var. serotina) forest in eastern North Carolina. Pine reproduction and other vegetation were inventoried initially and annually

for five years on 128 plots, half of which were protected from grazing, and the effects of wildfires were evaluated. Grazing influences were mostly favorable to the forest. The better forage species such as cane (Arundinaria) and palatable browse were reduced 59-60 percent, and the total understory vegetation about 25 percent, by 4 years of heavy grazing. Light fuels were reduced correspondingly. Reduction of competing vegetation increased the growth rate of small pine seedlings 23-67 percent, but had no effect on seedlings taller than the cane and brush (about 3 ft.). Seeding establishment increased more than 50 percent on grazed plots, but mortality of seedlings less than 1-ft. tall was 6-13 percent greater than on ungrazed plots. Aside from skid trails and roads, logging had little influence on pine seedlings or other understory vegetation. Fire was found to be essential for regenerating pond pine stands, not only by providing a favorable seedbed but also by releasing seed that had accumulated for several years in closed cones on the trees. On grazed unburned areas about 50 seedlings per acre were established each year, and fewer than 10 per acre without grazing. Following an intense fire, 2250 seedlings appeared the first year and 1700 more the next year. The second year influence indicated either an incomplete seed-cast or a considerable degree of dormancy in the seed. About one-sixth as many seedlings followed a light fire. Grazing before burning decreased the fire intensity and consequently its effect on seedling establishment. Although all understory species sprouted after a burn, cane was favored because it regained its former height in a few months and overtopped competing shrubs for several years. However, burning increased the susceptibility of cane to grazing damage. Cows made best gains on the less heavily stocked ranges, but calf gains were not affected significantly by the stocking rate. Heavy stocking produced considerably more beef per acre the first two years, but not in later years when the range deteriorated. Burning tended to increase cattle gains during the year of the fire, but not thereafter.--W. O. Shepherd.

Slatyer, R. O.
1957. the significance of the permanent wilting percentage in studies of plant and soil water relations. Bot. Rev. 23(10): 585-636.

Steen, E.
1958. betesinflytelser i svensk vegetation. [effects of grazing on swedish vegetation] Statens JordbrFörsök Meddel. 89, 82 pp. [English summary.]

On the basis of published results and of his own investigations, the author discusses the effects of grazing in Sweden, principally in relation to forest which, for the most part, forms the climax in sociological development. The changes produced by grazing in the vegetation of hitherto ungrazed areas is outlined, as are the individual effects of the three factors, grazing per se, droppings,

and treading. Finally the effects produced by different animals and the ecological effects of using different grazing techniques are discussed.--Herb. Abs.

Stewart, George, and Keller, Wesley.
1936. a correlation method for ecology as ememplified by studies of native desert vegetation. Ecology 17(3): 500-514.

Simple, partial, and multiple correlations show that Chrysothamnus stenophyllus and Oryzopsis hymenoides compete strongly with each other in the northern desert shrub associations of Millard County, Utah. This is likewise true of Hilaria jamesii and Sporobolus asperfolius, whereas Artemisia nova and O. hymenoides are apparently commensals. C. stenophyllus was found on heavily grazed areas to compete excessively with Eurotia lanata but not actively on moderately grazed areas. Soil heterogeneity of the desert soils was extremely high, and accounted for a large part of the difference in density of E. lanata on plots that were nearby but not immediately adjacent. The method of study exemplified, though both useful and definite, has been little used by ecologists.--Biol. Abs.

Thomas, A. S.
1959. sheep paths. observations on the variability of chalk pastures. Brit. Grassland Soc. Jour. 14(3): 157-164.

The variability of some chalk pastures above the Pewsey Vale in Wiltshire was studied by recording point-quadrats two inches apart on strips across sheep paths; the results are shown diagrammatically. There were usually lines of tall grasses at the edges of the paths, with belts of shorter grass, richer in forbs, between the paths. Some species of grasses and forbs were most common on or near the paths; others were more common in the short turf. The theoretical and practical implications of this variability are briefly discussed.

Vries, D. M. de.
1953. objective combinations of species. Acta Bot. Neerlandica 1(4): 497-499.

Distributional features of grassland species are arranged in a diagram that indicates frequency of association between species and type of soil (acid, lime, moist, dry, fertile, poor) in which the species occur.

_______, and Ennik, G. C.
1953. dominancy and dominance communities. Acta Bot. Neerlandica 1(4): 500-505.

A study of 855 Dutch grasslands showed that the more frequently a species occurs the more it is correlated with specific environmental factors. Thus Anthoxanthum odoratum occurs most frequently when the pH of the soil water is 5.7 ± 0.5, while Dactylis glomerata is most frequent at 6.7 ± 0.5.

Ward, George M.
1959. effect of soil fertility upon the yield and nutritive value of forages. a review. Jour. Dairy Sci. 42(2): 277-297.

The effects of fertilization of forage crops vary with soil types, relative levels of fertility within soil type, ratios of available nutrient crops, and climatic conditions. The chemical composition of forages may be altered by fertilization. Application of a nutrient in quantities greater than those required for maximum yield response usually results in luxury consumption of the nutrient. The nutrients whose level in plants may be increased by large applications include nitrogen, phosphorus, potassium, calcium, sulfur, and cobalt. The nitrogen and phosphorous levels in leguminous forage usually were not influenced by heavy applications of these nutrients. Biological assays of forages produced with different fertilizer treatments have yielded varying results. Several studies with sheep and rabbits have indicated that applications of phosphorous fertilizer increase the biological value of forages when these forages are fed alone or in highly simplified rations. Application of limestone to the soil has been shown to exert a favorable effection the biological value of forage. Forages grown on light soils have lower biological value for guinea pigs than do forages grown on heavy soils. Other reports indicate no difference in biological value of forage due to level of soil fertility.--Biol. Abs.

Weaver, J. E.
1924. plant production as a measure of environment. a study in crop ecology. Jour. Ecol. [London] 12: 205-237.

These studies were made in true prairie (Stipa-Koelaria) at Lincoln, Nebraska, in mixed prairie (Stipa-Bouteloua) in north central Kansas, and in the short grass plains (Bulbilis-Boutelous) at Burlington in eastern Colorado. At each station all the important aerial and edaphic ecological factors such as rainfall, water and nutrient content of soil, humidity, evaporating power of the air, soil and air temperature, and wind movement were measured and compared during three growing seasons. Plant production of native grasses and the smaller cereal crops was determined by the employment of a large number of clipped quadrats. The relative production of certain legumes and of maize was also determined. It was early determined that the water relations of soil and air were controlling, other factors being merely contributory. The yield of pure stands of short-grass (Bulbilis dactyloides and Bouteloua gracilis), wheat grass (Agropyrum glaucum), mixed short and tall-grasses, and mixed tall grasses was found to decrease from

the true prairie through mixed prairie to short-grass plains directly in proportion to available water-content of soil and inversely proportional to the evaporating power of the air. The same relation was determined not only for the smaller cereals but also for alfalfa, sweet clover, and maize. The plant yield at each station during different seasons also correlated well with the variations in the water relations. Since deficiencies in water content were most marked late in summer, the differences in plant production were often greatest in late maturing tall-grasses at the eastern stations. Thus, native and crop plants are shown to integrate environmental conditions and to express them quantitatively in yield.

Wheeler, J. L.
1958. the effect of sheep excreta and nitrogenous fertilizer on the botanical composition and production of a ley. Brit. Grassland Soc. Jour. 13(3): 196-202.

Results are presented for the final two years of a previously described experiment. The return of dung and urine by sheep to a ryegrass/white-clover ley was controlled by suitable harnesses to give four treatments (no dung or urine, dung, urine, dung and urine) which were combined in a replicated factorial design with four levels of nitrogenous fertilizer application (0, 52, 182, 312 lb. N per acre). Applied nitrogen and urine were the dominant factors affecting botanical composition. The percentage of ryegrass increased and that of clover decreased with the progressive increases in nitrogen application. Volunteer species (mainly Poa spp.) contributed up to 20 percent by the final year, the maximum occurring under the medium-high nitrogen treatment. Urine restricted the incursion of weed grasses. Combined with urine or the full return of excreta, high levels of applied nitrogen increased herbage production by up to 120 percent. There was little response to dung except at the highest nitrogen level. The yield response to applied nitrogen was almost linear. In the absence of animal returns response was poor, partly due to shortage of potash. When both excreta were withheld the light nitrogen dressing depressed the annual production compared with the control; where both excreta were returned together with this dressing no reduction occurred in annual yield and the spring yield was improved ($p < 0.05$).

Wicht, C. L.
1948. a statistically designed experiment to test the effects of burning on a sclerophyll scrub community. I. preliminary account. Roy. Soc. So. Africa, Cape Town, Trans. 31(5): 479-501, illus.

Five blocks of 6-year-old scrub regrowth were laid out, and in each of these the eight burns on the 15th day of the months January to April and September to December were made in random quadrants. Each quadrant included 4 sq. m. A careful analysis was made of the

quadrants before treatment. This gave some idea of the magnitude of the differences that would have to develop in the different burns before they could be accepted as statistically significant. The results of the January to April burns, as observed in the succeeding winter and spring, are described. Burning had no immediate adverse effect on moisture or organic material in the surface soil layers. The experiment provided no evidence that germination of the seeds and development of geophytes were either promoted or retarded by fire. Burning in summer and autumn will generally promote the flowering towards the end of winter and spring of *Oxalis* spp., other geophytes, and probably some therophytes. But such burning will prevent the flowering, for one season at least, of many perennial shrubby species, especially those that redevelop from seed. It also appeared probable that late burning in autumn was more unfavorable for flowering in spring than burning in midsummer.--Biol. Abs.

N. QUANTITATIVE PLANT DISTRIBUTION

1. PLANT DISTRIBUTION - SINGLE SPECIES

Archibald, E. E. A.
1948. plant populations. I. a new application of neyman's contagious distribution. Ann. Bot. [London] (n.s.) 12(47): [221]-235, illus. [See CONTAGIOUS DISTRIBUTIONS]

Arrhenius, O.
1923. statistical investigations in the constitution of plant associations. Ecology 4(1): 68-73.

Ashby, Eric.
1935. the quantitative analysis of vegetation. Ann. Bot. [London] 49(196): 779-802, illus. [With an appendix by W. L. Stevens.]

Statistical examination of data from 4000 quadrats, of two sizes, taken at random in a population of Salicornia europea, showed that the individuals were distributed almost at random in the uniform environment, but there was a small but significant aggregation of the individuals. The relation between percentage frequency and density is given approximately by $p = 1-e^{-kx}$ where p is the probability of finding a species of density x in a quadrat of area k. Percentage frequency (defined by Raunkiaer as the percentage occurrence of species in a number of quadrats taken at random) is therefore not a satisfactory index to the density of a species. Support is given to Kylin's suggestion that J-shaped skew distribution of species in percentage frequency classes depends on the fact that frequency classes of equal width do not correspond to equal density classes, and is no indication of homogeneity of a community.--Biol. Abs.

Bartlett, M. S.
1948. determination of plant densities. Nature [London] 162(4120): 621.

Reaffirms that the most efficient size of quadrat is with about 20 percent absence (product of quadrat size and plant density about 1.6; there is reasonable efficiency from 0.7 to 3).

Beall, Geoffrey.
1940. the fit and significance of contagious distributions when applied to observations on larval insects. Ecology 21(4): 460-474.

The theoretical distributions of J. Neyman (Ann. Math. Statis. 10: 35-57) were tried against four distributions, obtained by recording the number of insects on unit areas in the field. Neyman's distributions of Types A, B and C all corresponded well, with C somewhat the best, to data on the European corn borer, Pyrausta nubilalis, and the best webworm, Loxostege sticticalis, but did not correspond to data on the Colorado potato beetle, Leptinotarsa decemlineata. The difference in these results apparently occurred because the larvae of the two former species formed a comparatively homogeneous age-group but the larvae of the latter species a most heterogeneous group. Some success was obtained in estimating, from the distribution of the larvae, the mortality and dispersion to which they had been subject from the time of hatching.

Blackman, G. E.
1935. a study by statistical methods of the distribution of species in grassland associations. Ann. Bot. [London] 49(196): 749-777, illus. [With an Appendix by M. S. Bartlett.]

The nature of the statistical distribution of species over small areas in a number of grassland associations was subjected to critical analysis. Some 12,000 quadrats were observed. Some species, of which the individual plants could be distinguished, showed a random distribution (Poisson type). Others, e.g., Plantago media, Primula auricula, were not distributed at random. In stoloniferous and other species the density was estimated by area covered or number of tillers; the distribution curves were markedly asymmetrical, the "skewness" being greatest for occasional and least for dominant species. The relation found between quadrat size and average number of species did not agree very closely with the theoretical relationship calculated on the assumption of random distribution of all the species, but exclusion of the rarer species improved the agreement. If a species is distributed at random, the logarithm of the percentage absence is directly proportional to density. Estimation of percentage absence in the quadrat is liable to little personal error, is rapid, and has much to recommend it for an ecological study of botanical changes. On theoretical grounds, the most accurate measure of density is to be obtained by using a quadrat of such a size that the percentage absence is 20-30 percent.--Biol. Abs.

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1942. statistical and ecological studies in the distribution of species in plant communities. I. dispersion as a factor in the study of changes in plant populations. Ann. Bot. [London] (n. s.) 6: 351-370.

Böcher, Tyge W.
1935. om en metode til undersøgelse af konstans, skudtaethed og homogenitet. [on a method for investigating constancy,

shoot density and homogeneity.] Bot. Tidsskr. [Copenhagen] 43(4): 278-304, illus. [English summary.]

The method is a modification of Raunkiaer's method for determining frequency. However, the author was able, by dividing the radius of the circle into four equal parts, to investigate the occurrence of the species within four circular areas, one outside the other, the innermost being 0.01 sq. m., the outermost 0.9 sq. m. Examples are given of analyses carried out by the new method, and comparative investigations of some types of vegetation are recorded.--Biol. Abs.

Böcher, Tyge W., and Bentzon, Michael Weis.
1958. density determination in plant communities. Oikos 9(1): 35-56, illus.

Böcher's (1935) modification of Raunkiaer's method of frequency analysis is further modified. Instead of using circles of four different sizes and of awkward areas, concentric circles of three sizes are utilized, covering areas of 0.1, 0.01, and 0.001 sq. m. The apparatus used is simply an alpenstock with an attached crosspiece that indicates the radii of the three circles. In practice, all species occurring within the innermost (smallest) circle are listed, then all additional species in the middle-sized circle, and finally all additional species in the largest circle. This procedure is repeated 10 times at random locations. The results are treated statistically. The method is elucidated by the analysis of communities of lichens at Korshage, Northern Seeland, Denmark. It is concluded that by use of this method it is possible to detect and analyse rather small differences in the composition of the vegetation in such communities of small plants. In a second part of the paper the mathematical basis of the density determinations is examined. It is found that the method gives a broader range of discrimination than the older method, but that the accuracy within the range is somewhat smaller.--Biol. Abs.

Cain, Stanley A., and Evans, Francis C.
1952. the distribution patterns of three plant species in an old-field community in southeastern michigan. Mich. Univ. Lab. Vert. Biol. Contrib. 52, 11 pp., illus.

The distribution patterns of populations of *Lespedeza capitata*, *Liatris aspera*, and *Solidago rigida* were obtained by taking the bearing and distance from a reference point of all individuals encountered in an area of approximately two acres. By means of these data, the location of each individual plant was plotted on a map. An overlay grid representing 1-meter-square quadrats was used to prepare frequency charts for the distribution of each species. Different relationships between the three species were indicated by the data for density, mean area, frequency, and abundance. The tendency to clumping appeared to be greatest in *Lespedeza*, least in *Solidago*, and

intermediate in _Liatris_. A distinction was made between "major" clumps, which are probably due to clonal development resulting from localized seed dispersal or from vegetative reproduction, and "minor" clumps consisting of several individuals only, which may represent either the beginning of such clones or the chance associations resulting from random dispersal. The ability of _Solidago_ to spread by rhizomes may account in part for the greater development of minor clumps in this species, while the possession of heavier seeds helps to explain the greater degree of major clumping in _Lespedeza_.--Auth. sum.

Clapham, A. R.

1936. over-dispersion in grassland communities and the use of statistical methods in plant ecology. Jour. Ecol. [London] 24(1): 232-251.

The data presented by T. L. Steiger in "The Structure of Prairie Vegetation" [see Ecology 11: 170-217, 1930] are studied statistically to determine the mode of distribution of the recorded species. Of 44 species tabulated, the relative variance exceeds one in 42 cases, and is less in but two cases. In random dispersion the relative variance equals one and the excess over one indicates that most of the species were less uniformly dispersed than random and tend to be patchy. The relative variance tends to increase with increase of the mean density of each species. When the quadrats were divided into classes having 0,1,2,3, etc., individuals of a species per quadrat, there was also a deviation in the size of the classes from what would be expected from random dispersion. And the deviations increased with mean density. The author concludes that in the prairies of eastern Nebraska the individuals of most of the species show strong over-dispersion. He suggests this may be due to the methods of reproduction of the species, as vegetative propagation tends to form denser patches around the older plants which have a greater than mean density. He also suggests that over-dispersion may greatly increase the difficulty of determining the mean density of the different species from a set of random quadrats.--Biol. Abs.

Cottam, Grant.

1951. phytosociological measurements of non-random plant distributions. Ecol. Soc. Amer. Bul. 32: 58.

Curtis, John T.

1955. a note on recent work dealing with the spatial distribution of plants. Jour. Ecol. [London] 43(1): 309.

A set of field data used in several theoretical investigations is shown to be invalid since it was based on a subjective choice of the location of samples.

Curtis, J. R., and McIntosh, R. P.
1950. the interrelations of certain analytic and synthetic phyto-sociological characters. Ecology 31(3): 434-455, illus.

An artificial population with numbers of species and individuals arranged on a log-normal curve was used to study the effect of quadrat size on the mathematical relations between frequency, density, mean area, abundance, constancy, and presence. Theoretical expectations were realized for species with a random areal dispersion, but species with contagious dispersions showed lower frequency and constancy values than expected. Various well-known measures of nonrandomness were markedly affected by the size of the quadrat used in the sampling. Examples from American field studies indicated that the apparent randomness of tree species increased with increasing diameters.

David, F. N., and Moore, P. G.
1954. notes on contagious distributions in plant populations. Ann. Bot. [London] (n.s.) 18(69): 47-53. [See CONTAGIOUS DISTRIBUTIONS]

________, and ________
1957. a bivariate test for the clumping of supposedly random individuals. Ann. Bot. [London] (n.s.) 21(82): [315]-320, illus.

A method is proposed for the analysis of plant distributions from the relative positions of individual plants rather than from the numbers of plants occurring in successive small areas. The method is illustrated by reference to the detailed distribution in nature of Solidago rigida and of plants infected with nettlehead, a virus disease of hops.--Auth. abs.

Dice, Lee R.
1948. relationship between frequency index and population density. Ecology 29(3): 389-391.

From counts made of three species of plants on a series of random yard-square plots in a field in southern Michigan, it is shown that neither of the three species is distributed at random over the area. The frequency index of each species, consequently, gives a very erroneous estimate of its population density. The densities calculated from the frequency indexes range from about 2/3 to less than 1/10 of the actual densities obtained by counts of the individuals.

Evans, Francis C.
1952. the influence of size of quadrat on the distributional patterns of plant populations. Mich. Univ. Lab. Vert. Biol. Contrib. 54, 15 pp., illus.

The distributional patterns of populations of Lespedeza capitata, Liatris aspera, and Solidago rigida occurring in an old-field grassland community in southeastern Michigan have been subjected to analysis by quadrats of several different sizes. The size of quadrat was found to affect the resulting values of frequency and abundance, as well as the frequency distributions of the number of individuals per quadrat. It was also shown to have a marked effect upon various measures of dispersion. This demonstration suggests the desirability of utilizing several sizes of quadrat in securing samples for the study of distribution patterns and other phytosociological characteristics. If data for several quadrat sizes are available, a frequency-density curve may be derived that will enable one to determine qualitatively the degree to which the observed distributions depart from randomness and to compare material obtained with quadrats of different size.--Auth. sum.

Evans, Francis C., and Cain, Stanley A.
1952. preliminary studies on the vegetation of an old-field community in southeastern michigan. Mich. Univ. Lab. Vert. Biol. Contrib. 51, 17 pp., illus.

An abandoned field on the Edwin S. George Reserve, of the University of Michigan in southeastern Michigan, is being investigated to study the organization and operation of a natural community. Two principal community types are recognized within the field: a dense growth of Poa pratensis, which characterizes the hollow depressions or swales, and the vegetation of the upland areas, which is dominated by Poa compressa and Aristida purpurascens. Studies of frequency, biomass, density, and spacing indicate that the prevailing vegetation of the field is a secondary grassland, with which are associated various species common in this region to such comparatively sterile, exposed habitats. Most of the plants of the Poa-Aristida community of the upland areas in the field show some tendency towards clumping, and the mosaic or patchwork character of the vegetation is clearly evident. There is a slow successional trend towards deciduous forest, which formerly covered the field and which now adjoins it along much of its periphery. Within the framework of succession there appear to be more rapid microsuccessional changes, which repeat themselves over and over in the form of a cycle, marked by pioneer, building, mature, and degenerating stages, with the established grasses representing the mature stage.--Auth sum.

Fracker, S. B., and Brischle, H. A.
1944. measuring local distribution of ribes. Ecology 25(3): 283-303. [See CONTAGIOUS DISTRIBUTIONS]

Gleason, H. A.
1920. some applications of the quadrat method. Torrey Bot. Club Bul. 47: 21-33.

Gleason, H. A.
1929. the significance of raunkiaer's law of frequency. Ecology 10(4): 406-408.

Lynch, D. W., and Schumacher, F. X.
1941. concerning the dispersion of natural regeneration. Jour. Forestry 39(1): 49-51, illus.

Although reproduction is not distributed at random on cut-over areas, analysis of recently published data from the western pine type shows that a range in size of quadrats from one to four milacres leads to strictly consistent estimates.

McGinnies, W. G.
1934. the relation between frequency index and abundance as applied to plant populations in a semiarid region. Ecology 15(3): 263-282, illus.

Under ideal conditions, there is a high degree of correlation between frequency index and abundance. Under field conditions, although the relationship between frequency index and abundance is somewhat altered, there is still a high degree of correlation. Under both conditions, abundance can be calculated for a given frequency index by means of the proper curve or equation. There is a high degree of correlation between the frequency indices obtained simultaneously for 1 sq. m. and 0.1 sq. m. quadrats. Furthermore, the frequency index for 0.1 sq. m. quadrats multiplied by 10 approximates the abundance on the 1 sq. m. quadrats. The 1 sq. m. quadrat gives the lowest n/FI ratio for the less abundant species, and 0.1 sq. m. quadrat gives the lowest for the more abundant species. The size of the quadrat used should be determined by the character of the vegetation and the purposes of the study.--Auth. sum.

Machin, E. J.
1948. determination of plant densities. Nature [London] 162: 257.

In surveying plant associations, it is usual to determine the valence by noting the presence or absence of each species in sample areas, and the density by counting the number of individuals of each species in the same, or other, sample areas. Two difficulties are frequently encountered in determining densities by this method, the length of time needed in the field and the intermingling of root systems of individual plants of the same species with consequent indecision as to the exact number present in the sample. The following method has the advantage of requiring one set of observations only, from which valence and density may be determined, and of avoiding counts within the sample areas. Suppose the species has a density N/A plants per unit area and that a sampling area a is taken t times at random. Then the expected number of plants per trial will be aN/A, and the

number y_0 of trials containing no individuals of the species would be expected to be given by the expression

$$y_0 = t \exp(-aN/A).$$

$$\text{Whence } \frac{N}{A} = \frac{1}{a} \cdot \log_e \cdot \frac{t}{y_0}.$$

If the number of trials is 50 and the sampling area 0.1 square meter, a graph relating density and y_0 can be drawn and shows a remarkable sensitivity for densities 33 per sq. m. to 3 per sq. m. By increasing the sampling area to 1 sq. m., the density values on the graph are reduced ten times, and we have a sensitive range from 3.3 per sq. m. to 0.3 per sq. m. Much time has been saved in the field and results are reasonably in accord with densities found by the more laborious method. [Entire article.]

Numata, Makoto.
1950. the investigation of vegetation by means of sampling method. studies on the structure of plant communities. V. Bot. Mag. [Tokyo] 63: 149-154.

The significance of the difference between several sampling methods is indicated by analysis of variance. The relative number of sampling units required for a given degree of accuracy according to sampling methods is calculated from the average comparable variance.

Romell, L. G.
1930. comments on raunkiaer's and similar methods of vegetation analysis and the "law of frequency." Ecology 11(3): 589-596.

As a complement to Kenoyer's (1927) and Gleason's (1929) articles, an account is given of the efforts of some Scandinavian authors to analyze or explain the F percentage-curve (distribution of species in classes of frequency of representation on a number of sample areas). The peculiar mosaic-structure of numerous plant associations is not accounted for by the ordinary statistical and probability formulae based on normal dispersion. Frequency numbers computed from empirical F percentage-numbers by current formulae are therefore liable in many cases to give erroneous results. For the same reason, statistical analyses of vegetation by means of methods of the Raunkiaer type (presence-absence sample-plot methods) cannot be compared, if made with different sizes of sample areas, since there is no way of correcting the values for another size of area. The desirability is stressed of a common agreement on a standard size of sample area for such analyses and on the definition of the statistical units. Attention is drawn to the valuable Lagerberg-Raunkiaer method of estimating cover, which has received inadequate attention and has recently been grossly misinterpreted.--Auth. sum.

Singh, B. N., and Chalam, G. V.
1937. a quantitative analysis of the weed flora on arable land. Jour. Ecol. [London] 25(1): 213-221, illus. [See OTHER FREQUENCY DISTRIBUTIONS]

_______, and Das, K.
1939. percentage frequency and quadrat size in analytical studies of weed flora. Jour. Ecol. [London] 27(1): 66-77, illus. [See OTHER FREQUENCY DISTRIBUTIONS]

Thompson, H. R.
1958. the statistical study of plant distribution patterns using a grid of quadrats. Austral. Jour. Bot. 6(4): [322]-342, illus.

The statistical theory of the method of analysis of variance on a grid of contiguous quadrats is examined and the results from theoretical models for plant communities giving rise to nonrandomness in the field discussed. Some field data are analyzed and the theoretical and practical results correlated to determine the efficiency of the method as a practical technique. The large element that chance variation plays in practice makes it essential for several samples of the same community to be taken so that real and chance effects can be distinguished. A knowledge of the morphology of the species under consideration is desirable, for then some idea of the expected analysis of variance is available and there should be no confusion between different models.--Auth. sum.

West, Oliver.
1938. the significance of percentage area determinations yielded by the percentage area or density list method of pasture analysis. Jour. Ecol. [London] 26(1): 210-217. [See OCULAR ESTIMATE]

Whitford, Philip B.
1949. distribution of woodland plants in relation to succession and clonal growth. Ecology 30(2): 199-208.

A random quadrat study was made of 26 forest stands representing various successional stages in the prairie-forest border region of Wisconsin. Three arbitrary tolerance classes were established and the stands were classified as oak-hickory, intermediate, and maple-basswood on the basis of the percentage of basal area of trees in each class. The quadrat data showed that typical woodland species commonly are contagiously distributed in the earlier stages of succession and tend to become better dispersed, or more random, as succession advances. Species more typical of prairie and early forest stages sometimes tend to poorer dispersion again in their relict stages as the

climax is approached. The ratio of abundance (number of stems per occupied quadrat) to frequency, termed the A/F ratio, was used as a relative measure of dispersion. Hypothetical curves were constructed for abundance, frequency, and density of any species in advancing succession, showing that density and frequency reach their maxima in that order within the optimum ecological range of the species, while for most species there is a distinct peak in abundance in the early stages of invasion. All stands studied had some species of distinctly contagious distribution, indicating that statistical studies based upon an assumption of random distribution are of doubtful validity.

Williams, C. B.
1950. the application of the logarithmic series to the frequency of occurrence of plant species in quadrats. Jour. Ecol. [London] 38(1): 107-138. [See OTHER FREQUENCY DISTRIBUTIONS]

Wilson, J. W.
1959. analysis of the spatial distribution of foliage by two-dimensional point quadrats. New Phytol. [London] 58(1): 92-101. [With Appendix by J. E. Reeve.] [See POINT]

2. PLANT DISTRIBUTION - SEVERAL SPECIES

a. Frequency-Distribution Curves and Other Relations

Aberdeen, J. E. C.
1958. the effect of quadrat size, plant size, and plant distribution on frequency estimates in plant ecology. Austral. Jour. Bot. 6(1): [47]-58, illus.

The theoretical foundation for frequency estimates, as used in plant ecology, is discussed. An equation is derived in which the absence value is linked with the quadrat size, the plant unit size, the plant density, and the aggregation of the plant units. Graphical methods are used to estimate the density and the average size of the individuals of a species for a random distribution. Departure from a random distribution can also be detected by these methods. It is shown that if an estimate of the average plant unit size is combined with the frequency estimates, then the reliability of the results is increased considerably. The value of frequency estimates made with one, two, or more sizes of quadrats is discussed.--Auth. sum.

Archibald, E. E. A.
1949. the specific character of plant communities. I. herbaceous communities. Jour. Ecol. [London] 37(2): [260]-273, illus.

Data for the frequency of occurrence of the species in quadrats of different sizes for 10 herbaceous communities are presented as a preliminary to a statistical analysis which will be directed towards defining the specific character of these communities in quantitative terms. It is assumed that the plant community occupies a finite area and consists of a finite number of species, both of which are determined by the dominant species in conjunction with the climatic, topographic and edaphic factors. A new form of folding frame for a multiple quadrat which facilitates sampling is described. A method is suggested for estimating the commonness and rarity of species and it is noted that for the plant populations under consideration the common and rare species are less numerous than the species which are represented by individuals of intermediate density.--Auth. sum.

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1949. the specific character of plant communities. II. a quantitative approach. Jour. Ecol. [London] 37(2): [274]-288, illus.

Plant communities can be divided into those with a large pattern unit and those with a small pattern unit according to whether the pattern unit is greater or less than 1 sq. m. The "pattern" is defined by

the 50 percent area (x_{50}), which is the area on which an average of half the total number of species in the community occur, and by the specific density (y_0), which is the average number of species per sq. cm. If the average number of species per unit area is plotted against the logarithm of the area, an S-shaped curve is obtained. This curve can be approximated by the equation

$$\log_{10} \frac{y}{S-y} = k(\log_{10}x - \log_{10}x_{50}),$$

where y is the average number of species on area x, S is the total number of species in the community, and k is a constant. From a consideration of the greatest number of species which can populate 1 sq. cm., the largest area over which ecological conditions are likely to remain constant, and the total number of species in the community, a scale for the pattern of plant communities is developed and, as an example, it is shown how the probable limits for herbaceous angiosperm communities in the British Isles may be defined.--Biol. Abs.

Archibald, E. E. A.
1952. a possible method for estimating the area covered by the basal parts of plants. So. African Jour. Sci. 48(9): 286-292, illus.

When percentage frequency is plotted against the logarithm of the area of the quadrat, a series of S-shaped curves for different fractions of cover is obtained. The point of inflection of these curves is variable. In using percentage frequency to estimate basal cover, it is found that the average size of the cluster of individuals of a species (or of the individual itself if distribution is random) must be considered one of the variables. Size of the quadrat from which an estimate of the basal area covered by the species can be made is determined by the point of inflection of the curve. By the multiple quadrat method information concerning all species in the community can be obtained in a single survey. The method is considered practicable provided an equation can be found to express the increase in percentage frequency with increase in sample area.--Biol. Abs.

Fisher, R. A., Corbet, A. Steven, and Williams, C. B.
1943. the relation between the number of species and the number of individuals in a random sample of an animal population. Jour. Anim. Ecol. [London] 12(1): 42-58.

Large collections of Lepidoptera captured in Malaya and in a light trap at Harpenden serve as bases for developing a detailed statistical treatment. Special tables are presented for facilitating the calculations involved.--Biol. Abs.

Gleason, Henry Allen.
1922. on the relation between species and area. Ecology 3(2): 158-162, illus. [See SPECIES-AREA CURVES AND MINIMUM AREA]

Grant, J. A. C.
1951. the relationship between stocking and size of quadrat. 35 pp. Ontario: Univ. Toronto Press.

The stocked quadrat system, attributed to Lowdermilk, is a method for rapid surveys of vegetation and attempts to eliminate the shortcomings of stocking figures based on number of seedlings per acre. An area is broken up into squares and quadrats of perhaps 1/500 to 1/1000 acre in size and a randomly selected number of such quadrats is merely classified as stocked or unstocked. A quadrat will be classified as stocked if it contains at least one seedling. The ideal size of a quadrat must be such that one seedling on each quadrat would ultimately lead to a fully stocked stand of several hundred trees per acre. Obviously no account is taken of mortality, no allowance is made of the fact that mature trees may grow in clumps, or that ideal stocking at maturity is not necessarily ideal stocking at the regenerative stage of a plant community. Despite these and other shortcomings, useful results have been obtained from surveys made with the stocked quadrat system. The author discusses the influence of the size of the quadrat used on the stocking figures obtained, and shows that different sized quadrats give significantly different results. This fact poses the problem of how to convert stocking figures obtained with one size of quadrat to those of a different size. If x (expressed as a decimal fraction of unity) represents the stocking observed when using a quadrat size of, say, p milacres, then the corresponding stocking figure for a quadrat of $q=rp$ milacres, is given by the formula $y=1-(1-x)^r$. The quantity, $1-x$, is the probability that a randomly selected quadrat is not stocked. Assuming that the probabilities of stocking on neighboring quadrats are independent, then the probability that a contiguous quadrat of size rp would not be stocked is $(1-x)^r$, and conversely, the probability that a contiguous quadrat of size $q=rp$ is stocked is $1-(1-x)^r$. This formula therefore permits conversion of stocking data from quadrats of one size to those of another. The proposed conversion formula represents an approximation only as the probability of stocking on one quadrat is not unrelated to the probability of stocking on a neighboring quadrat. Bias inherent to the formula can be reduced by subdividing an area on which a stocking survey is made into more homogeneous blocks or strata. It is explained, and documented with numerical data, that the actual stocking figure for a new size of quadrat lies between the original figure x, and the value y given by the conversion formula.

Hanson, Herbert C., and Ball, Walter S.
1928. an application of raunkiaer's law of frequence to grazing studies. Ecology 9: 467-473.

This study shows that Raunkiaer's Law of Frequency may be used to advantage in grazing studies. It has been used to bring out and summarize differences in two adjacent range pastures, one grazed by the deferred and rotation system, the other by the continuous system. The frequency ratio in the former was 62, 14, 7, 7, 10 and in the latter 59, 13. 13, 11, 4. The first ratio is nearer than the latter to the normal ratio of distribution as developed by Raunkiaer. The variation between the two is due to the decrease in the palatable plants that are not resistant to continuous grazing and to the increase in unpalatable invaders or palatable species highly resistant to grazing in the continuously grazed pasture.

Kenoyer, Leslie A.
1927. a study of raunkaier's law of frequence. Ecology 8(3): 341-349.

McGinnies, W. G.
1934. the relation between frequency index and abundance as applied to plant populations in a semiarid region. Ecology 15(3): 263-282, illus. [See PLANT DISTRIBUTION-SINGLE SPECIES]

Romell, L. G.
1930. comments on raunkiaer's and similar methods of vegetation analysis and the "law of frequency." Ecology 11(3): 589-596. [See PLANT DISTRIBUTION-SINGLE SPECIES]

Arrhenius, O.
1920. distribution of species over the area. K. Vetensk. Akad. Nobelinst. Meddel. [Uppsala] 4(7): 1-6.

____ 1921. species and area. Jour. Ecol. [London] 9: 95-99.

____ 1923. on the relation between species and area. -- a reply. Ecology 4(1): 90-91.

Cain, Stanley A.
1935. ecological studies of the vegetation of the great smoky mountains. II. the quadrat method applied to sampling spruce and fir forest types. Amer. Midland Nat. 16(4): 566-584, illus.

A brief description is given of examples of two forest types in the Great Smoky Mountains National Park; the red spruce type (Piceetum rubentis) and the southern balsam fir type (Abietum fraseri). A method of sampling the arborescent strata (similar to that widely in use for nonarborescent communities) is described, based on a random sample by minimum area quadrats. The minimum area quadrat is determined for each community type by the form of species-area curves. The surveys based upon different numbers of minimum area quadrats are compared statistically by use of basal area data to determine the necessary number of quadrats to be studied. Forest types, sub-types, and site classes will probably be found to be characterized by certain species inferior to the tree layer, although the present paper does not contain definite studies of that aspect. It is thought that Abies fraseri must be recognized as forming, in the Great Smoky Mountains at least, a forest type in which it is the sole dominant.--From auth. sum.

____ 1936. the composition and structure of an oak woods, cold spring harbor, long island, with special attention to sampling methods. Amer. Midland Nat. 17(4): 725-740, illus.

The tree-layer of a small woods dominated by Quercus montana was sampled by three methods: a single square plot (50 X 50 m.); a strip (10 X 250 m.); 25 scattered quadrats (10 X 10 m.). The data for each method were secured on a basis of basal area by 100 sq. m. units and species-area curves were drawn. For statistical analysis of the wood as a whole the method of scattered quadrats was best. If, however, the forest-type is to be considered on a basis of subtypes, resulting

from small changes in topography, the single plot method, one plot per subtype, is a more efficient and yet an adequate method. Data are also given for the complete flora by life-form groups, the biological spectrum, basal area, density, coverage, frequency.--Biol. Abs.

Cain, Stanley A.
1938. the species-area curve. Amer. Midland Nat. 19(3): 573-581, illus.

The species-area curve expresses the relationship between areas of different sizes and the number of species found on those areas. Such curves have been constructed using as areas entire stands of an association, single plots of standard area one in each stand, plots of increasing area and scattered plots of constant area within single stands. These curves rise rapidly at first and with increased area tend to become asymptote with the x axis. The point where the curve flattens strongly is taken to indicate minimal area for the association, minimum quadrat size (for constancy or frequency data), or minimum quadrat number according to the purpose or manner of construction of the curve. It is shown that the shape of the curve depends on the ratio between the two axes. Hence it is necessary to standardize the y-x ratio or to determine mathematically the region of the curve where 10 percent increase of area gives 10 percent increase of species (or a 5 percent relationship, if greater accuracy is desired).--Biol. Abs.

______ 1943. sample-plot technique applied to alpine vegetation in wyoming. Amer. Jour. Bot. 30(3): 240-247.

Minimal area was determined to be 32 sq. m. for alpine fell-field vegetation of the Snowy Range. For scattered plots in this type of vegetation, 1/10 sq. mi. (1 X 10 dm.) is large enough if 20 plots per stand are studied. Statistical data are presented for 5 typical stands. The species of greatest statistical importance in this area are Arenaria sajanensis, Selaginella densa, and Sieversia turbinata, with respect to frequency, coverage, constancy, and presence. When compared with other regions, the southern Wyoming alpine fell-field community appears to be typical of that of comparable situations in the Southern Rocky Mountains.--Biol. Abs.

DuRietz, G. Einar.
1922. uber das wachsen der anzahl der konstanten arten and der totalen artenanzahl mit steigendem areal, in natürlichen pflanzenassoziationen. [the increase in number of constant species and the total number of species with increasing area, in natural plant associations.] Bot. Notiser [Sweden] 1922: 17-36, illus.

Gilomen, H.
1926. neuere methoden zur untersuchung der pflanzengesellschaften. [newer methods of investigating plant communities.] (Abstract). Naturf. Gesell. in Bern. Mitt. 1925: 19-21.

The relationship between area and number of species seems better expressed by Kylin's than by Arrhenius' formula. Homogeneity may be expressed by a curve based on number of species.--Bot. Abs.

Gleason, Henry Allan.
1922. on the relation between species and area. Ecology 3(2): 158-162, illus.

Discusses fallacy in Arrhenius' reasoning regarding the mathematical relation between number of species and area.

——— 1925. species and area. Ecology 6(1): 66-74.

Goodall, D. W.
1954. minimal area: a new approach. VIII^{e} Cong. Internatl. Bot., Paris Raps. et Commun. Sect. 7: 19-21.

Hopkins, Brian,
1955. the species-area relations of plant communities. Jour. Ecol. [London] 43(2): 409-426.

Twelve natural British plant communities have been studied and their species-area curves all show, with increase in area, a rapid initial rise in number of species, the rate of which gradually decreases. Their species-log area curves all show, with increase in area, a very gradual rise in number of species, the rate of which increases until, on fairly large areas, the curve becomes very steep and approximately linear. Curves of a logarithmic nature have been fitted to the observed data and a reasonably good fit was obtained. The ecological meaning of the parameters used in the equation is discussed.

——— 1957. the concept of minimal area. Jour. Ecol. [London] 45(2): 441-449.

The views of the Zürich-Montpellier and Uppsala schools of plant sociology on the concept of minimal area are discussed. The Zürich-Montpellier school define the minimal area of a plant community as the point ("break") where the species-area curve becomes approximately horizontal. The Uppsala school define the minimal area as

the point ("step") where the constancy-area curve becomes approximately horizontal. Later work has expressed doubt as to the existence of the "break" and "step" in these curves. The results from the analysis of 12 natural British plant communities are analyzed by means of species-area, species-log. area, constancy-area and constancy-log. area curves. No evidence for either the "break" or "step" is found. It is concluded that minimal area cannot be determined from either the species-area curve or from the constancy-area curve and doubts are expressed as to the existence of the minimal area.

Kurljuškin, M. I., and Petrov, M. P.
1938. [determination of a minimum area for description of the vegetation on the arthrophytetum caricosum pastures in the desert of kara-kum.] Sovet. Bot. [Moskva] (3): 84-95.

Statistical elaboration of data from tests showed that, owing to the scattered vegetation, larger areas must be used. To attain an accuracy of 5 percent occurrence on the Arthrophytetum caricosum pastures, a transect of 3.1 ha. (10m. X 1550m.) was adequate; for a precision of 10 percent occurrence (sufficient for grazing purposes) the transect may be reduced to 0.45 ha. On the mixed Arthrophyteto-Haloxylonetum caricosum pastures (with a better vegetation than the previous type) the transect may be reduced to 0.4 and 0.25 ha. respectively for 5 and 10 percent accuracies.--Herb. Abs.

Penfound, William T.
1945. a study of phytosociological relationships by means of aggregations of colored cards. Ecology 26(1): 38-57.

This investigation is concerned with the effects of changes in quadrat size, number of species, and total cover on the sampled frequency, density, and cover of species by means of an analysis of aggregations of colored cards. Frequency percentages, the frequency relation among species and the number of species in the frequency classes of Raunkiaer all vary with quadrat size, number of species, and total plant cover. Density (number per unit area) does not vary with quadrat size but does change with the number of species and the degree of cover. The density relation among species does not vary with quadrat size, number of species, or total plant cover. Actual cover (areal spread) per species does not vary with quadrat size, although it does shift with the number of species or the total plant cover; the cover relation among species is unaffected by quadrat size, number of species, or total plant cover. Of the three concepts, frequency is the most artificial and the least important, whereas cover is considered the most valuable. Size of the quadrat cannot be predetermined if frequency, density, and cover are to be studied. The number of quadrats to be utilized as a sample depends on the quadrat size employed. Our data suggest a relatively large number of quadrats, at least 10 times the "break in species-area curve," as a proper quantitative sample in community analysis.--W. T. Penfound.

Penfound, William T.
1948. an analysis of an elm-ash floodplain community near norman, oklahoma. Okla. Acad. Sci. Proc. 28: 59-60.

Concerns a fourth-level-floodplain elm-ash forest. The site, relatively wet and with little herbaceous cover, was once occupied by a cottonwood-willow forest. Quadrats 13.2 ft. on a side seem to be of proper size to "delineate frequency, number, cover, and basal area." It was believed that at least 50 quadrats of the size employed are necessary for the analysis.

_______, and Watkins, Allan G.
1937. phytosociological studies in the pinelands of southeastern louisiana. Amer. Midland Nat. 18(4): 661-682, illus.

The longleaf pine and slash pine-pond cypress communities of S.E. Louisiana are characterized by park-like stands of tall, slender trees with no shrub stratum but with a well-developed prairie-like herbaceous layer. Andropogon virginicus was the most important species in the longleaf pine habitat; in virgin, second-growth, and cut-over longleaf pine units. Other important species were A. scoparius, Aristida virgata, and Elephantopus nudatus. In the slash pine-pond cypress swamp the species of highest frequency and cover-grade included Arundinaria tecta, Erigeron vernus, Eriocaulon decangulare, Rynchospora gracilenta, and Sphagnum species. Grasses and sedges contributed 37 percent of the 166 species listed in all communities and are to be considered as the controlling species. Since the species-area curves break most strongly before the 15th quadrat is reached and since the species encountered after the 15th quadrat are very low both in frequency and in covergrade, 15 quadrats of 1 sq. m. each seem sufficient for a phytosociological analysis of herbaceous vegetation.--Biol. Abs.

Rice, Elroy L.
1952. phytosociological analysis of a tall-grass prairie in marshall county, oklahoma. Ecology 33(1): 112-116, illus.

A total of 39 species was found in the prairie community. Of these, Sorghastrum nutans, Panicum virgatum, and Andropogon gerardi were considered the dominants. Andropogon scoparius, usually considered the most important dominant in the tall-grass prairie of Oklahoma, was considerably less important than the above species in the community studied. Characteristic species of the present prairie community were delineated fairly well on the basis of either 20 or 40 0.1 sq. m. quadrats. The actual data for cover and frequency differed somewhat for most species if based upon 20 vs. 40 quadrats. The present data suggest that several times the number of quadrats required for the break in the species-area curve would be needed to obtain exact reproducible data on cover and frequency.

Rice, Elroy L., and Kelting, Ralph W.
1955. the species-area curve. Ecology 36(1): 7-11, illus.

Chief use of species-area curve in U.S.A. has been in indicating minimal quadrat size and minimal numbers of quadrats required for adequate sampling. These applications of curve necessitate location of so-called break in curve. Cain suggested that sampling is adequate when a 10 percent increase in sample area results in a 10 percent increase in number of species. Such a point on species-area curve can be easily located mechanically. In 1943, Cain pointed out that location of such a point as that suggested above on species-area curve depends on total area sampled. Despite this warning and those of Ashby, Vestal, and Goodall later, many persons have continued to use the 10 percent point on the species-area curve especially for determining adequacy of sampling. It was decided that a careful restatement of defects of such a procedure documented with results of field experiments might be of value. Species-area curves were drawn from data obtained from many sources. Several 10 percent points were usually located mechanically on each curve, each point being determined on basis of a difference number of quadrats. In all cases it was found that the 10 percent point of Cain moved upward along curve with each addition in number of quadrats. Since 10 percent point shifts with a change in number of quadrats used in locating it, it would seem that such a point has little value as an indicator of adequacy of sampling.--Auth. Abs.

Vestal, Arthur G.
1949. minimum areas for different vegetations: their determination from species-area curves. Ill. Biol. Monog. 20(3): 1-129, illus.

Species-numbers are plotted, using logarithmic scale for areas. Curves are of S-form, convex in the upper section. On a given curve, two reference areas are found by locating two points which satisfy empirical ratios (adopted after many trials): Af or "fair-sized stand," is 50 X Ar or "smallest representative area," and has twice the number of species. Am or "minimum area" is then found: it is 5Ar, with ca. 1.44-1.5 times the number of species in Ar. It is assumed that a reference area in one vegetation is equivalent, in at least some respects, to the same reference area in any other vegetation. For many purposes, Ar is a sufficient one-piece sample; Am is a fairly conservative standard. "Minimal areas" found by authors using other methods are usually between these two reference. areas and their species-numbers were found for about 240 examples of vegetation (and a few animal assemblages) from many regions. Examples are mostly from published descriptions (briefly summarized). Necessary conversions of data are described. Minimum areas found range from 0.025 milacre (0.1 sq. m.) with 12 species for small lichens on rock, to 21 acres with 100 species for mora forest in British Guiana. A detailed table, a graph, and a "procession of curves" summarize this wide range in magnitude. Numerous phenomena of vegetation, e.g., richness of composition, and peculiarities of heterogeneous

communities, are incidentally explored. There are sections on geometry of S-curves; on departures of curves from the form determined by Fisher's logarithmic series; on implications for sampling, for modified field methods, for conserving natural areas, and for classifying vegetation; and on hypotheses to explain species-area relations.--A. G. Vestal

Vestal, Arthur G., and Heermans, Mary Frances.
1945. size requirements for references areas in mixed forest. Ecology 26(2): 122-134.

This study determines areal units just large enough to give specific kinds of information in two old-growth mixed forests. Such reference areas may be useful as a basis for comparing different communities. The plot size found effective for number of tree species (including an average of 13 species of the 25 in a fair-sized stand) appears to be the same as the "smallest representative area," which is 0.8 acre, which gives adequate representation of leading species (12 species in this type). It was found, by testing frequencies of different combinations of these 12 species in plots varying from 0.1 to 6.4 acres, that 0.8 acre includes, in 7 or 8 of 10 plots, at least 10 of these species, and most of their combinations. A 4-acre unit further tells approximate order of abundance among species and identifies the type. This "minimum area for assignment to type" proves to be the same as the "minimal area" of plant sociologists (if trees only are considered). When 7/10 of all the species are represented, the trees are numerous enough (504 in 4 acres) to indicate proportions among species. A brief name for this reference size is "minimum area." Close agreement of two tracts in these forests may not be expected with much less than 20 acres. This size gives a dependable statement of composition and is called "definitive area." A dependable array of diameter-distributions, showing form of stand, requires about 80 acres. This unit embodies most characteristics of a stand, and is termed "complete stand." Estimates of reference areas in some other forest types are made: with fewer species, or if very large old trees are lacking, areas 2/9 to 5/9 as large are equivalent to the sizes here found. The smallest unit that can be called a stand is considered to be minimum area.

3. FLORISTIC SIMILARITY, GENERIC DISTRIBUTION, AND INTERSPECIFIC CORRELATION

Beazley, Ronald, and Shiue, Cherng-Jiann.
1957. further applications of skewness and central tendency tests with the rectangular distribution as a criterion. Forest Sci. 3(4): 321-328.

Three sets of field data were used to demonstrate the application of the skewness and central tendency tests previously designed by the authors. These include a forest reproduction survey, a seed source study and a forest thinning experiment. Interpretations in biological terms for each case are given to develop the meanings of these statistical tests.--Biol. Abs.

Cole, LaMont C.
1957. the measurement of partial interspecific association. Ecology 38(2): 220-233.

Each individual sample or collection in a series can be classified into one of four categories according to whether two species, A and B, are both present, both absent, or one species present and the other absent. It is then possible to determine whether or not two species occur together more often than would be expected by chance (positive association), less often than would be expected (negative association), or simply seem to occur together by chance. A coefficient has been defined to measure the strength of association. Statistical reliability can be determined. Association might result from actual attraction between species, or it might result if both are attracted to some third species or to some other environmental feature characterizing a portion of samples. Coefficients of partial association are derived to make it possible to distinguish actual attraction from mutual association with third species. Coefficients are measures of such partial association and permit tests of statistical significance so that one can reach conclusions: Species A and B are significantly more closely associated when C is absent than when C is present.--L. C. Cole.

Dawson, G. W. P.
1951. a method for investigating the relationship between the distribution of individuals of different species in a plant community. Ecology 32(2): 332-334.

From data published by Steiger on the number of individuals of _Andropogon furcatus_, _A. scoparius_, _Bouteloua curtipendula_ and _Poa pratensis_ occurring in each of 40 quadrats of High Prairie Grassland in America, the partial correlation coefficients were calculated for these species by pairs. Significant positive correlations were found between

A. furcatus and P. pratensis and between A. scoparius and B. curtipendula. In similar data from Low Prairie Grassland the same significant correlations were found. It is suggested that when quadrat data of this type are available the calculation of such partial correlation coefficients (which are to be preferred to ordinary correlation coefficients) will provide useful clues to the spatial arrangement of plants of different species in a community, thus crystallizing problems for investigation in the field.

Dice, Lee R.
1945. measures of the amount of ecologic association between species Ecology 26(3): 297-302.

The coefficient of association of Forbes indicates the amount of association between two given species compared to the amount of association between them expected by chance. To provide a simple direct measure of the amount of association of one species with another, the association index is proposed. If a is the number of random samples of a given series in which species A occurs and h is the number of samples in which another species B occurs together with A, then the association index B/A = h/a. Similarly, if b is the number of samples in which species B occurs, then the association index A/B = h/b. There is also proposed a coincidence index, 2h/(a+b), whose value is intermediate between the two reciprocal association indices. As a measure of the statistical reliability of the deviation shown by the samples of a given series from the amount of association expected by chance, the chi-square test may be used.--Auth. sum.

Fager, E. W.
1957. determination and analysis of recurrent groups. Ecology 38(4): 586-595, illus.

A new index of affinity between species, based on presence and absence, is proposed and a table is provided from which the significance of an observed number of joint occurrences can be estimated. Using this index, together with a four-part definition of a recurrent group, a procedure is described which indicates the largest, most frequent, separate groups within which all species formed a nearly constant part of each other's biological environment. Ranking methods are suggested for examining interspecific concepts, such as numerical dominance, relative abundance, concordance and correlations within these groups.--Herb. Abs.

Forbes, S. A.
1925. method of determining and measuring the associative relations of species. (Abstract.) Science (n.s.) 61: 524.

Formulae which show the ecological affiliation of pairs and groups of species are discussed.

Guyot, H.

1924. association standard et coefficient de communauté. [a standard association and a coefficient of community.] Soc. Bot. de Genève Bul. 15: 265-272.

An ideal standard association is advocated. A comparison of the number and frequency of the species in any given association and the standard association may be expressed as a ratio termed the "coefficient of community."

Hanson, H. C.

1934. a comparison of methods of botanical analysis of the native prairie in western north dakota. Jour. Agr. Res. 49(9): 815-842, illus. [See SIZE AND SHAPE OF SAMPLING UNIT]

Jaccard, Paul.

1929. considération sur le coefficient générique et sa signification floristique et phytosociologique. Soc. Bot. de France Bul. 76(1/2): 47-66.

The author gives further emphasis to his former thesis that the generic coefficient, (number of genera $\times$ 100)/number of species, varies inversely with ecological diversity of the area under consideration. He illustrates this by comparing the flora of the richly diversified district of Herault (generic coefficient 31 percent) with the more uniform district of Auvergne (generic coefficient 35 percent). It is now announced that when the flora of a country is in a condition of relative stability and account is taken of Linnean species only, the generic coefficient of the entire flora, of the Dialypetalae, of the Gamopelalae, the Compositae, and of the Monocotyledonae agree very closely. For the flora of France the coefficients of these groups are respectively 20.3-, 19.7-, 20.1-, 20.7-, and 20.0 percent. If subspecies, varieties and ecotypes are included the agreement is not so close. When the generic coefficients of various plant families depart materially from those of the great groups mentioned above it may be assumed that the ecological conditions in the region are particularly favorable or decidedly detrimental to particular plant families.--Biol. Abs.

______ 1939. cas particulier concernant le coefficient générique. Soc. Vaud. des Sci. Nat. Bul. [Switz.] 60(248): 249-253.

______ 1941. sur le coefficient générique. Chron. Bot. [Leiden] 6(16): 361-364.

In comparing the generic coefficient (ratio of the number of genera corresponding to 100 species in a given community) for various territories, the author finds a distinct correlation with the ecological variations shown.

Jaccard, Paul.
1941. sur le coefficient générique. II. Chron. Bot. [Leiden] 6(17/18): 389-391. [Concluded from Chron. Bot. [Leiden] 6: 361-364.]

A relationship exists between the generic coefficient and the degree of frequency of associated species. This furnishes a valuable tool to the plant sociologist for comparing the floras of limited territories.

Koch, L. F.
1957. index of biotal dispersity. Ecology 38(1): 145-148.

"Geobiology" is proposed as the name of science of all spatial transactions of living organisms. Its two principal fields of investigation are biogeography and ecology. Biogeography includes study and interpretation of geographical, distributional patterns, whereas ecology is the study and interpretation of physio-morphological influences of environmental factors on living organisms. Attention is drawn to contributions of P. Jaccard to biogeographical theory, and to the virtual disregard of his work by Americans as apparent from ecological and biogeographical literature. One primary objection to the usage of Jaccard's Coefficient of Community is that it cannot be applied to more than two biotas. This difficulty is eliminated by a proposed Index of Biotal Dispersity (IBD). This index is suggested as a numerical measure of biotal homogeneity of biogeographical areas. An example of the use of IBD is based upon data which are derived from known distribution of mosses in California.--L. F. Koch.

Margalef, Ramón.
1956. información y diversidad especifica en las comunidades de organismos. [information and specific diversity in communities of organisms.] Invest. Pesqueras [Barcelona] 3: 99-106, illus.

The well-known "diversity indices" may be substituted by expressions, borrowed from information theory, that are free of the postulate of a certain regularity in the distribution of individuals into species. The "mean entropy" per individual, as computed by the expression of Brillouin, $D = \frac{1}{N} \log \frac{N!}{N_1!\, N_2! \ldots N_s!}$, where N is the total number of individuals and N_1, N_2, ...N_s, the number of individuals of each species 1, 2, ...s, gives results in agreement with those supplemented

by other diversity indices, but of wider application. Degrees of increase in "diversity," when confounding samples separated in space or time, provides a useful tool for the study of spatial heterogeneity and for the analysis of population sequence.

Margalef, Ramón.
1957. la teoria de la información en ecologia. [information theory in ecology.] Barcelona R. Acad. de Cién. y Artes, Mem. 32(13): 373-449, illus.

This paper begins with a discussion of mathematics generally used at present in biology, and its inadequacy. Then there is a long treatment of methods of describing mixed populations in terms of information theory, with many equations and charts, and illustrations taken from analysis of plankton in Vigo estuary. Some topics discussed are: diversity or richness in species of mixed populations, study of spatial structure of communities, dynamics of mixed populations, and application to other organic structures.--Biol. Abs.

Shiue, Cherng-Jiann, and Beazley, Ronald.
1957. classification of the spatial distribution of trees using the area sampling method. Forest Sci. 3(1): 22-31.

A method has been designated to provide a means of consistently classifying spatial tree associations by areal plots in relative terms of probable departure of skewness and central tendency from a rectangular distribution. Two tests are involved, one for central tendency and one for skewness. The clumpness and evenness of tree distribution on the ground can be expressed as the departure of skewness and central tendency from the rectangular distribution. A table and figure showing the departures due to skewness and central tendency respectively, from the rectangular distribution at probability levels 0.25 and 0.05 have been constructed. Differences in spatial distribution between two species or two plant communities can also be tested in terms of the skewness and central tendency with reference to a rectangular distribution.

Vries, D. M. de.
1956. ecological results obtained by the use of interspecific correlation. European Grassland Conf. Papers. 1954: 32-36.

Williams, C. B.
1944. some applications of the logarithmic series and the index of diversity to ecological problems. Jour. Ecol. [London] 32(1): 1-44, illus. [See OTHER FREQUENCY DISTRIBUTIONS]

Williams, C. B.

1947. the generic relations of species in small ecological communities. Jour. Anim. Ecol. [London] 16: 11-18.

Evidence as to whether conditions are more or less favorable to species of the same genus as compared to species in different genera can be found in the relative number of species and genera in small compared with large natural communities of animals and plants. Evidence has previously been brought forward to show that in large groups of animals and plants the number of genera with 1, 2, and 3 or more species is closely represented by the mathematical "logarithmic series." New evidence is here given to show that the same order exists in the genera and species of quite small ecological communities. The "index of diversity" is a measure of the extent to which the species are grouped into genera, and it is independent of the size of the sample. If the index is high, there are many genera in relation to the number of species; if the index is low, there are fewer genera in relation to the number of species. The index of diversity is lower in the small community than in the large fauna and flora. The evidence indicates, therefore, a selection by nature in favor of > 1 species in the same genus rather than in favor of single species in different genera.--Auth. sum.

______ 1947. the logarithmic series and its application to biological problems. Jour. Ecol. [London] 34(2): 253-272, illus. [See OTHER FREQUENCY DISTRIBUTIONS]

______ 1949. jaccard's generic coefficient and coefficient of floral community, in relation to the logarithmic series and the index of diversity. Ann. Bot. [London] (n.s.) 13(49): 53-58.

Evidence has been accumulating to show that the frequency distribution of the relative abundance of individuals in species, and of species in genera in plant communities can be closely represented by a logarithmic series (see Williams, Jour. Ecol. 34: 253). If this interpretation is correct it is possible to calculate an "Index of generic Diversity" and an "Index of specific Diversity" for any population which is being sampled. Jaccard's Coefficients are then each a double function depending partly on the Index of Diversity and partly on the size of the sample. Thus in a population structure based on the logarithmic series the "Index of Diversity" is a better ecological measure than Jaccard's Coefficients.--C. B. Williams.

Ashby, Eric.
1935. the quantitative analysis of vegetation. Ann. Bot. [London] 49(196): 779-802, illus. [With an appendix by W. L. Stevens.] [See PLANT DISTRIBUTION - SINGLE SPECIES]

——— 1936. statistical ecology. Bot. Rev. 2: 221-235.

——— 1948. statistical ecology. II. a reassessment. Bot. Rev. 14(4): 222-234.

The application of statistical methods to the analysis of vegetation is critically examined in the light of publications since 1936. The following conclusions are reached: (a) statistical methods are of no value in the classification of plant communities; (b) statistical methods are valuable in the analysis of the distribution of individual species. There is abundant evidence that most species are over-dispersed, and an important problem in statistical ecology is to work out quantitative methods of studying over-dispersion.--Biol. Abs.

Bray, J. Roger, and Curtis, J. T.
1957. an ordination of the upland forest communities of southern wisconsin. Ecol. Monog. 27(4): 325-349.

Fifty-nine stands of upland hardwood forest in southern Wisconsin were studied by means of a new ordination technique, which considered the degree of similarity of two stands as shown by their coefficient of community value could be translated into a spatial pattern in which the inverse of the coefficient was equated with linear distance. By means of a geometric method of arc projection and intersection, three vegetational gradients were constructed. These gradients were used as independent axes to give a 3-dimensional orientation of the 59 stands. It was found that species in three dimensions formed atmospheric distributions with high values in a restricted portion of the array, surrounded by decreasing values in all directions. Each distribution was interspersed to varying degree with that of other species, in a continuously changing pattern. Correlation of environmental factors was made with the three gradients, and some interaction patterns between vegetation and environment were initially described. --Biol. Abs.

Clark, Phillip J.
1955. grouping in spatial distributions. Science 123(3192): 373-374.

Clark, Phillip J., and Evans, Francis C.
1955. on some aspects of spatial pattern in biological populations. Science 121(3142): 397-398.

Clausen, J. Johanna.
1957. a comparison of some methods of establishing plant community patterns. Bot. Tidsskr. [Copenhagen] 53(3): 253-278, illus.

A study was carried out to determine what differences in pattern occur when three sets of correlation coefficient values for the same group of communities are derived independently from the three measures of frequency, presence and relative frequency. Sampling of the 47 communities studied was by means of 10-20 quadrats, 0.01 sq. m. in size, per community. The methods of arrangement tested were: one dimensional inspection by the methods of Bray [see Herb. Abs. 26: 1308 and 1314] and Sorensen (1955); two dimensional inspection. The results are discussed.--Herb. Abs.

Curtis, John T., and Greene, H. C.
1949. a study of relic wisconsin prairies by the species-presence method. Ecology 30(1): 83-92.

All higher plants were listed for each of 65 relic stands of relatively undisturbed prairie in Wisconsin. The stands were grouped on a physiographic basis into high prairie, low prairie, dry limestone prairie, and sand prairie. Of the 237 species found, two (Andropogon furcatus and Euphorbia corollata) had a presence (stand-frequency) of 80 percent or more, 19 were found in 50 percent or more of the stands, and 88 appeared in less than 10 percent of the stands. Only the high prairie and the dry limestone prairie had an index of homogeneity [(number of species with 50+ percent presence/total number of species) 100] greater than 25 percent.

DuRietz, G. E., Fries, T. C. E., Osvald, H., and others.
1920. gesetze der konstitution natürlicher pflanzengesellschaften. [the constitution of plant associations.] Flora och Fauna 7: 1-47.

This publication is a theoretical discussion of the idea and law of constants, the ratio of constants to the area, the results of the application of the law of constants to the association complex and to larger vegetation regions, etc.--Bot. Abs.

Ferrari, T. J., and others.
1957. factor analysis in agricultural research. Netherlands Jour. Agr. Sci. 5(3): 211-221.

Investigation is made into the factors determining the botanical composition of grassland, with a special application (pp. 216-220) of factor analysis to the spring growth of grass.--Herb. Abs.

Goodall, D. W.

1952. quantitative aspects of plant distribution. Cambridge Phil. Soc. Biol. Rev. 27(2): 194-245.

A review, covering the random or aggregated distribution of individuals, the relation between frequency and density, species-area and frequency-distribution curves, the logarithmic series and index of diversity, interspecific correlations, vegetational homogeneity, minimal area, and the classification of vegetation based on quantitative measurements.--Biol. Abs.

______ 1953. objective methods for the classification of vegetation. I. the use of positive interspecific correlation. Austral. Jour. Bot. 1(1): [39]-63, illus.

It is argued that correlations between the presence or quantity of different species recorded in quadrats imply heterogeneity in the vegetation in which the quadrats were placed. If the quadrat data can be so divided that within each subdivision no interspecific correlations occur, these subdivisions represent elementary classification units of the vegetation, and an objective classification may be arrived at if methods can be found of satisfying this requirement. Four procedures are described for dividing a set of quadrat data into groups satisfying the above criterion of homogeneity. The simplest and apparently the most satisfactory consists in finding the most frequent species showing significant correlations with others, and separating in the first instance all quadrats containing this species. Within this group correlations are again tested, and the process is repeated until a group with no significant correlations has been extracted. All other quadrats are then lumped together and the process is begun again from the beginning. When the whole collection of quadrat data has been divided in this way into homogeneous groups, these groups are recombined where this can be done without the resulting larger group showing interspecific correlations. The four procedures suggested are illustrated on data from a small area of the Victorian Mallee. Some of the results suggest that classification is an inappropriate method of dealing with variation in this type of vegetation, and that a coordinate treatment might be more suitable. --Auth. sum.

______ 1953. objective methods for the classification of vegetation. II fidelity and indicator value. Austral. Jour. Bot. 1(3): [434]-456, illus.

A new index of fidelity is described, based on the ratio of frequencies for the species in two communities. The importance of significance tests in determining characteristic species is emphasized. The value of a species as indicator of a particular community is taken as the ratio of the frequency in that community to the frequency elsewhere within the area studied. An index to express this is proposed. The value of discriminant functions in enabling vegetation samples of uncertain affinities to be allotted to one of several possible communities is demonstrated. An example is given in which this technique has been used to determine whether one community can be regarded as intermediate between two others, or has special features of its own. The paper is illustrated by data taken from publications of the Zürich-Montpellier school, and by original data collected in the Victorian Mallee.--Auth. sum.

Goodall, D. W.
1954. objective methods for the classification of vegetation. III. an essay in the use of factor analysis. Austral. Jour. Bot. 2(3): [304]-324, illus.

The possibilities of using the statistical technique of factor analysis in describing variations in plant communities are explored. This method enables the variations to be treated as continuous, instead of resulting in a separation of the stands studied into a limited number of discrete associations or other synecological categories. It further provides a means for testing whether such separation can be objectively justified. It may often facilitate the recognition of the complexes of environmental factors which mainly determine differences in vegetation, and provides a means of estimating the relative value of the various species as indicators of these environmental complexes. In the present paper, the "principal axes" technique of factor analysis is applied to the analysis of data for percentage cover for 14 species in the Victorian Mallee. It is shown that their distribution, in so far as it does not depend on factors peculiar to individual species, can be represented in terms of at most five orthogonal "factors." The two most important "factors" are interpreted in terms of catenary changes in the vegetation. Other less common species not included in the analysis show high correlations with these "factors." In units of 1.28 ha. there is no evidence that more than one continuously varying population is represented in the area; but in units of 25 sq. m. the majority of quadrat records fall into one or other of two principal categories, representing the valley and ridge communities. The potential value of factor analysis in plant sociology, and difficulties in its application to this field, are discussed.--Auth. sum.

Greig-Smith, P.
1952. the use of random and contiguous quadrats in the study of the structure of plant communities. Ann. Bot. [London] 16(62): 293-316, illus.

Individuals of many species are nonrandomly distributed. The nature of such nonrandomness is discussed and the occurrence of a mosaic pattern of phases, the phases having the same species at different densities, is suggested as one cause of nonrandomness. Artificial "communities" of discs have been sampled by random quadrats of various sizes and by a grid of contiguous quadrats. The variance shown by grid data has been analyzed into components contributed by blocks of grid units of increasing size. These experiments have shown that (1) use of a single quadrat size is not sufficient to detect nonrandomness; (2) grid sampling of a clumped distribution, where the clumps are under-dispersed, or of a mosaic of phases of different densities, gives a graph of variance against block size with a peak at the block size corresponding to the mean area of clump or mean size of mosaic unit; (3) if clumps are random or over-dispersed no significance can be attached to any peak in the variance graph. Such distributions are, however, likely to be detectable by observation in the field. The use of a grid gives more information than random quadrats on the nature of a nonrandom distribution and can detect mosaic patterns not revealed by subjective methods. It can also be used where random quadrats are impractical, e.g., in forest.--P. Greig-Smith.

Greig-Smith, P., and Kershaw, K. A.
1958. the significance of pattern in vegetation. Vegetatio [The Hague] 8(3): 189-192.

Horikawa, Y., and Itow, S.
1958. the vegetational continuum and the plant indicators for disturbance in the grazing grassland. Jap. Jour. Ecol. 8(3): 123-128. [In Japanese with English summary.]

Nineteen vegetation stands of a grazing grassland, located at Sayôto in the Chûgoku Mountains were investigated as to the distributional pattern of plant populations and the indicator plants for disturbance. Each stand was sampled with 250 quadrats (20 × 20 cm.), and the quantitative relations of the plant populations were expressed as frequency percentages. The distributional interchange of four principal species was tested by the method of the leading dominant, and the adaptation number for these species was decided. To express the numerical distance between the treated stands, frequency index of each stand was calculated by the following formula:

$$\text{Frequency Index} = \frac{(a \times 1) + (b \times 2) + (c \times 3) + (d \times 4)}{a + b + c + d} \times 100$$

in which a, b, c, and d are the frequency percentage of Miscanthus sincensis, Arundinella hirta, Zoysia japonica, and Plantago asiatica, respectively. The resulting index has a range from 100 to 400, and in this study from 133 to 390. The treated stands were arranged along the numerical order of the index.--Biol. Abs.

Hosokawa, T.

1955-56. an introduction of 2 × 2 table methods into the studies of the structure of plant communities. (on the structure of the beech forests, mt. hiko of s.w. japan) Jap. Jour. Ecol. 5(2): 58-62, 1955; 5(3): 93-100, 5(4): 150-153, 1956. [In Japanese with English summary.]

In this paper first are given an introduction and critical discussions to Cole's index (Cole, 1949), Goodall's Indicator Value (Goodall, 1953) and Goodall's objective method of grouping plant communities (Goodall, 1953), all of which are based on 2 × 2 table treatments of statistics. The index of Goodall's indicator value is modified by the writer so as to indicate it in a form of coefficient values between +1.00 and -1.00. The structure of the beech forests on Mt. Hiko is studied by means of those 2 × 2 table methods. Chi-square values of those major component species are shown with their values of Cole's Index. According to a modification of Goodall's method (1953), four different kinds of plant communities are distinguished from each other in the stand of Sasamorpheto-Fagetum crenatae of Mt. Hiko; the Sasa nipponica group, Rhododendron metternichii group, Fagus crenata group and Fraxinus spaethiana group. Each group seems to correspond to "Facies" in the concept of Braun-Blanquet.

_______, Omura, M., and Nishihara, Y.

1957. grading and integration of epiphyte communities. Jap. Jour. Ecol. 7(3): 93-98.

The conception on which the modified method of classifying vegetation is founded is that if there is neither species of positive nor negative interspecific correlation of significance level in any given plant group, such a group is conceived of as being of homogeneous construction. Then, the epiphyte vegetation is classified objectively by four procedures according to this method of consideration, on the basis of floristic composition, into some homogeneous groups by making use of the value of interspecific correlation based on the frequency of major component species and in the light of the indicator value of significance level (Goodall, 1953; Hosokawa, 1955-56). These groups would then be integrated into an appropriate number of groups of higher rank at a wanted level in accordance with the value of "Quotient of Similarity" (QS) (Sörensen, 1948) which is based on the frequency of component species. Accordingly, because of the success of our several years of varied studies of corticolous vegetation in the beech forests of Mt. Hiko, Southwest Japan, we would draw the conclusion that the four distinct communities of epiphytes, which are considerably developed there can be recognized.--Biol. Abs.

Hughes, R. Elfyn.

1954. the application of multivariate analysis to (a) problems of classification in ecology; (b) the study of the interrelationships of the plant community and environment. Eighth Internatl. Bot. Cong. Proc. 1954(7): 16-18.

Hughes, R. Elfyn, and Lindley, D. V.
1955. application of biometric methods to problems of classification in ecology. Nature [London] 175(4462): 806-807.

These methods are illustrated by comparison of two plant communities, and by study of classification of six soil series. Statistics and equations are given, and further applications are suggested.

Kershaw, K. A.
1957. the use of cover and frequency in the detection of pattern in plant communities. Ecology 38(2): 291-299, illus.

A method using frequency and cover data to determine the dimensions of heterogeneity in plant communities is outlined. Adjacent transect readings are grouped together into different block sizes, the variance of any block size rising to a peak at the mean dimension of an area of heterogeneity. The difficulty of testing the significance level of such a peak, once nonrandomness has been established, is discussed, and from the analyses of a series of experiments with artificial communities, a subjective approach to this problem is proposed. Field work has established cover as the more suitable measure of plant abundance, especially for work on grassland communities.--Auth. abs.

Labouriau, Luiz Gouvêa.
1948. nota sôbre o baricentro dos diagramas de frequência das associacões vegetais. [note on the mean of frequency diagrams of plant associations.] Rio de Janeiro, Jard. Bot. Arq. 8: 221-225.

This note proposes the abscissa of the mean of the frequency diagram of plant associations as a new index of homogeneity. Several concrete examples serve to compare this index with the degree of homogeneity defined in the author's note in Soc. Bras. de Agron. [Rio de Janero] Bol. 10(1): 49-55, 1947.--Auth. sum.

Numata, Makota.
1949. the basis of sampling in the statistics of plant communities. studies on the structure of plant communities. Bot. Mag. [Tokyo] 62(727-738): 35-38. [In Japanese with English summary.]

Sampling methods for studying the statistics of plant communities have hitherto been made by purposive selection of some standard areas or random sampling by the theory of large samples. A third method is suggested, i.e., random sampling by the theory of small samples. By this method it is possible to calculate the homogeneity of a plant community and then decide upon the number of sampling quadrats to estimate its analytical nature.

Pichi-Sermolli, Rodolpho E.
1948. an index for establishing the degree of maturity in plant communities. Jour. Ecol. [London] 36(1): 85-90.

The maturity index is the quotient of the total frequency percentages of all the species in the community divided by the number of species found on the station. The more highly developed the community the nearer to 100 is its maturity index.

Vries, D. M. de.
1948. method and survey of the characterization of Dutch grasslands. Vegetatio [The Hague] 1: 51-57.

Outline of author's plant sociological specific frequency plus percentage weight method of classifying grassland using 0.25 sq. dm. plots. Sixteen main types are distinguished for the Netherlands, each being characterized by a species that is sufficiently frequent, significant from agricultural viewpoint (indicating a good, fair, or bad sward), or is a useful indicator ecologically. Value of the main-type and type-forming species and reasons for choosing them are discussed, and a key to the 16 main types, in order of priority, is given.

Williams, W. T., and Lambert, J. M.
1959. multivariate methods in plant ecology. I. association-analysis in plant communities. Jour. Ecol. [London] 47(1): 83-101.

The method of Goodall (Austral. Jour. Bot. 1: 39-63, 1953) of subdividing a set of sample quadrats into homogeneous groups, in which all species-associations were made nonsignificant or indeterminate, is analyzed theoretically. A new sorting method is proposed, consisting of hierarchical division of the species with the highest aggregated value of the chosen association-index in the class under study. The properties of suitable indices are briefly considered; and in this hand-computed exploratory study, $\Sigma\chi^2$ (constructed from corrected χ^2 values) is used, nonsignificant and indeterminate values being taken as zero and equal weight being given to positive and negative associations. The statistical efficiency of the method is confirmed by its application to two heathland communities, and the nature of the ecological information obtained is assessed.--Biol. Abs.

_______, and Lance, G. N.
1958. automatic subdivision of associated populations. Nature [London] 182(4651): 1755.

Bourget, S. J., Elrick, D. E., and Tanner, C. B.
1958. electrical resistance units for moisture measurements: their moisture hysteresis, uniformity, and sensitivity. Soil Sci. 86(6): 298-304.

Six different types of electrical resistance units were evaluated for measuring soil moisture. Gypsum units were preferable at high tensions but the nylon-gypsum units were probably best suited for low tensions. A fiberglass gypsum unit developed by the authors offered the best compromise.--Authors.

Cline, Marlin G.
1944. principles of soil sampling. Soil Sci. 58(4): 275-288.

The soil is treated as a statistical population of sampling units and should be subdivided vertically and horizontally into homogeneous sampling volumes. The number of sampling units required to represent a homogeneous sampling volume can be estimated from knowledge of the range or variance by means of the relationship of t values to the standard error and the maximum sampling error permissible. Complete randomization is necessary for estimates of fiducial limits, but incomplete randomization gives an unbiased estimate of the mean. Compositing is an efficient means of obtaining adequate numbers of sampling units for objectives that require only an estimate of the mean. The relationship of subsampling error to maximum particle size and size of subsample is discussed.

______ 1945. methods of collecting and preparing soil samples. Soil Sci. 59(1): 3-5.

Methods are given for sampling soils (a) to represent an area for estimates of mean values, variability, and significance and (b) to represent a soil type. A procedure for preparation of samples is presented.

Downes, R. G., and Beckwith, R. S.
1951. studies in the variation of soil reaction. I. field variations at barooga, n.s.w. Austral. Jour. Agr. Res. 2(1): [60]-72, illus.

A study has been made of the variability of soil reaction, in the field, on Barooga Field Station, N.S.W., and on portion of a nearby property. Soil samples were taken at two depths, 0-4 in. and 4-8 in., at 4-chain intervals according to a rectangular grid. Other samples were taken at ½-chain intervals on restricted areas, and at 1-foot intervals on grids 4 feet by 3 feet. Differences of more

than 3 pH units have been found for samples taken in one continuous area of a single soil type, and differences in excess of 2.5 pH units for individual samples taken 4 chains apart. The differences between individual samples at distances of ½ chain and 1 foot were found to be as large as 1.2-2.0 pH units and 0.6-1.1 pH units respectively. The standard deviation of the differences between adjacent points was considerably smaller in the samples spaced at 1-foot intervals.--Auth. sum.

Hammond, Luther C., Pritchett, William L., and Chew, Victor.
1958. soil sampling in relation to soil heterogeneity. Soil Sci. Soc. Amer. Proc. 22(6): 548-552.

Raupach, M.
1951. studies in the variation of soil reaction. II. seasonal variations at barooga, n.s.w. Austral. Jour. Agr. Res. 2(1): [73]-82, illus.

The seasonal and spatial contributions to the variation in reaction of two Australian soils have been examined. Experiments described show seasonal effects to be slight and spatial variation contributions large. Exchangeable sodium from soluble salt variations is shown to give rise to the differences in reaction upon one soil while calcium and magnesium relationships may, among other factors, be responsible for those on the other.--Auth. sum.

_____ 1951. studies in the variation of soil reaction. III. variations at the waite agricultural research institute. Austral. Jour. Agr. Res. 2(1): [83]-91, illus.

Variations in reaction and total soluble salts of a red-brown earth from South Australia have been assessed. Seasonal changes are discernible for reaction but are largely masked by spatial variations even over small areas. The amplitude of the seasonal changes is of the order of 0.15 of a pH unit, the soil returning to the same pH value during the succeeding season. Spatial variations have been found for organic carbon, nitrogen, clay and exchangeable cations over small areas. Data have been presented to show that while the mean soil reaction does not vary widely, there is a variation in the variance of the reaction values about the mean with season. The change of the reaction status of the soil with time over a small area does not consist of a uniform increase and decrease of all the reaction values in the area but rather of a reorganization of all hydrogen ion contributing factors to give difference in dispersion about the mean value.--Auth. sum.

_____ 1954. the errors involved in pH determination in soils. Austral. Jour. Agr. Res. 5(4): [716]-729, illus.

Errors in replication of pH values of 1:5 soil-water suspensions are shown to differ significantly between routine observers and to be larger when duplicate determinations are made upon different days rather than on the same day. For the routine technique employed in these laboratories the 5 per cent. fiducial limits of a single determination do not rise above $\pm$ 0.09 pH units due to the above causes. Errors due to soil variation over small distances in the field may show 5 per cent. limits as high as $\pm$ 1.3 pH units. The causes of the errors which may arise within the measuring system are considered and details are given of errors in soil systems due to the suspension effect and to lack of equilibrium between the soil and aqueous phases. Absence of equilibrium may give differences as high as 1.0 unit when measurements are made upon sedimenting alkaline suspensions; no errors occur due to this cause below pH 5. The presence of salts does not modify the differences observed. The suspension effect is relatively small. It is recommended that where possible, pH measurements be made upon soil systems with the glass electrode in the suspension and the reference electrode in the dialysate or supernatant liquid. The description and use of a suitable electrode arrangement is given in an appendix. Generally pH measurements can be considered to no greater accuracy than $\pm$ 0.1 unit and quite often circumstances do not justify this precision.--Auth. sum.

Shiue, Cherng-Jiann, and Nai Lin Chin.
1957. direct use of pH values in statistical analysis of soil reactions. Soil Sci. 84: 219-224.

It is generally believed that soil reaction data in pH form should not be used for statistical analysis directly, unless the pH value is transposed into corresponding normality of hydrogen ions. Several statistical tests have been made on 3 sets of soil samples taken from both cultivated field and forest plots. When the soil reaction was expressed in hydrogen ion concentration form, the data have shown lack of normality, a slow approach to normality even when grouped as means, and a dependence of the standard deviation on the mean. It is not valid to make any parametric statistical analyses with such data directly. On the other hand, data in pH form usually satisfy the assumptions underlying most parametric statistical analyses. Therefore it is recommended that pH value should be used directly in statistical analyses, without transposing into the form of hydrogen ion concentration.--Authors.

Tisdall, A. L.
1951. variability in soil moisture and infiltration on two riverina soils. Austral. Jour. Agr. Res. 2(2): [126]-131.

Studies of variability in soil moisture and of a method for determining infiltration were conducted on two irrigated soils in the Riverina region, a sandy loam of the red-brown earth group and a clay of the grey and brown soil group respectively. Coefficients

[illegible]

[illegible]

[illegible]

It is generally believed that soil [illegible]

[illegible]

[illegible]

[illegible]

of variation were high in all cases. It is concluded that the use of 16 replicates gives adequate precision in the estimate of infiltration (C.V. of 8 and 12 per cent. for the two soils studied). Similarly, the use of 16 gravimetric determinations, each bulked from four sites, would give a satisfactory estimate for soil moisture (C.V. of less than 10 per cent. for the two soils studied). This number of samples is not excessive from practical considerations. Sampling for soil-moisture increment, following the type of irrigation used on these soils, should be carried out to a depth of two feet, but the duplication of gravimetric determinations is not warranted by the small increase in precision obtained.--Auth. sum.

Youden, W. J., and Mehlich, A.
1931. selection of efficient methods for soil sampling. Boyce Thompson Inst. Contrib. 9(1): 59-70. 3 fig.

Culvers gravelly silt loam from Broome County, New York, and Sassafras loamy coarse sand from the Camden area, New Jersey, were sampled at 9 stations scattered over an area of several square miles. At each station samples were collected at definite intervals and the acidity of the samples determined. The results show in each case that samples from widely separated points vary more than samples taken close together. This was also observed to hold for the lower horizons where the variation was not as great and tended to reach a maximum value characteristic of the soil type. The data analyzed statistically show the relative efficiency of various spacing for replicate samples when large areas are surveyed. Intervals as low as 10 ft., or 100 ft., were too small to constitute an effective method for sampling these areas. The sampling procedure was discussed with reference to its application in crop fertility studies, soil classification, and the investigation of possible damage to soils over large areas.--Auth. sum.

II. USE OF ANIMALS IN MEASURING HERBAGE PRODUCTION

TABLE OF CONTENTS

PART II

A. FORAGE INTAKE AND DIGESTION STUDIES

Axelsson, Joel, and Eriksson, Sture.
1950. comparison between the accuracies of the direct and the indirect methods in digestion trials with ruminants. K. Lantbr. Hogsk. Ann., Uppsala 17: 375-395.

The standard deviation of the coefficients obtained in trials with a certain feed (the experimental feed) run parallel at a station has been used as a measure of the experimental error of the digestion coefficients of the nutrients. Data of 1484 digestion experiments with cattle and sheep carried out at 20 experiment stations were collected from literature. The trials with cattle were carried out according to both the indirect (Eden's indirect method) and the direct method. In each feed where two or more digestion experiments had been run parallel, the experimental errors of the digestion coefficients were calculated, 306 errors of sole feed trials and 366 errors of difference trials being obtained. The results proved that in sole feed trials as well as in difference trials the experimental error of the digestion coefficient of each nutrient decreased with an increase of its content in the dry matter of the experimental feed. The decrease was most rapid at a small content. In difference trials, the experimental error of the digestion coefficient of organic matter decreased when the content of the dry matter of the experimental feed increased in percentage of the whole ration. Comparisons between the experimental errors of stations, methods and animal species indicated that the indirect method has given less reliable digestion coefficients than the direct method, though the difference was not significant. The errors in Jarl's calculations are pointed out. Between the errors of trials with cattle and sheep, the difference was not significant. In the main, the reliability of the digestion coefficients was more closely connected to the precision of the work than to the species or methods. However, since the indirect method is more expensive than the direct, it is to be recommended only in such cases as where the direct method cannot be followed.

Barnett, A. J. G.
1957. studies on the digestibility of the cellulose fraction of grassland products. 1. the relation between the digestibility of silage cellulose as determined in vitro and silage crude fibre digestibility determined by feeding trial. Jour. Agr. Sci. [England] 49(4): 467-474, illus.

Carbery, M., Chatterjee, Indubhusan, and Hye, Md. Abdul.
1934. studies on the determination of digestibility co-efficients. I. a new method of experimentation and computation for directly obtaining the digestibility co-efficients of individual feed nutrients in a mixed ration. Indian Jour. Vet. Sci. and Anim. Husb. 4(4): 295-340.

The difficulties associated with the prevailing methods of calculating digestibilities of feeds in rations either where single feeds deficient in some nutrient or where two or more feeds are involved in the diet are discussed. As alternatives, a graphical method and the use of multiple regressions for determination of digestibilities of feeds are proposed. The experimental design and procedure for such tests are presented and discussed. The chief advantage claimed for both of these methods is that they enable direct calculation without having recourse to the doubtful alternative of using assumed values for a part of the ration. Results obtained by these methods have conformed to the requirement of statistical tests of significance in the case of all the ration components (dry matter, organic matter, crude protein, ether extract, crude fiber, N-free extract) with the notable exception of crude fiber, possibly due to the fact that during digestion some special phenomenon intervenes, probably related to bacterial action on fats and fiber, which reacts in such a way on the food material in the digestive tract as to effect an apparent increase in the fiber fraction of the feces or undigested residue, thereby showing an apparent decrease in digestion.--Biol Abs.

Cipolloni, Mary Ann, Schneider, Burch H., Lucas, Henry L., and others.
1951. significance of the differences in digestibility of feeds by cattle and sheep. Jour. Anim. Sci. 10(2): 337-344.

Published data which allow the comparison of the digestive powers of cattle and sheep were analyzed statistically. Comparisons were made for the digestibility of organic matter, crude protein, crude fiber, N-free extract, and ether extract, and the contents of total digestible nutrients in each of the three feed classes, dry roughages, silages, and concentrates. To make the comparisons fair, covariance adjustment for proximate composition was conducted. Specific difference in the digestibility of the organic matter, crude fiber, N-free extract, and ether extract, and in the total digestible nutrient content of dry roughages were found to be statistically significant. In the case of silages and concentrates, species differences were significant only for ether extract. The interaction, species-by-feeds, was significant for the digestibility of protein in dry roughages and the digestibility of ether extract in concentrates, indicating that the differences in the digestibility favor cattle with certain feeds and sheep with others. Other differences, although not significant, were large enough to suggest a trend. Greater accuracy will be attained if digestibility data to be used for cattle are obtained with cattle, and similarly for sheep.

Crampton, E. W.
1939. pasture studies. XIV. the nutritive value of pasture herbage. some problems in its estimation... Sci. Agr. [Ottawa] 19(6): 345-357.

This paper is chiefly a critical discussion of the methods commonly employed in estimating the nutritive value of pasture herbage. The

limitations of certain fractions of the standard feeding-stuffs analysis as satisfactory criteria of feeding value are especially emphasized and illustrated by results obtained from rabbit feeding trials at Macdonald College as well as by data published in the literature. The usual feeding-stuffs analysis (chemical) does not partition the organic material of a feed into biological units, and hence their value in predicting feeding value is necessarily uncertain. As a possible improvement in this respect insofar as pasture herbage is concerned, a modification in the analytical plan is proposed whereby the "carbohydrate" fraction is to be separated into (1) lignin, (2) cellulose and (3) other carbohydrate instead of the present groups--crude fiber and N-free extract. Data are presented indicating that lignification of the herbage increases from spring to mid-summer and then decreases as cooler seasonal conditions reoccur, and that the nutritive value of the herbage is negatively correlated with the lignin trend. The need for "pilot" animals in studying the nutritive value of pasture herbage is stressed and the possibilities of rabbits for this purpose discussed.

Crampton, E. W., and Forshaw, R.
1939. pasture studies. XVI. the nutritive values of kentucky blue grass, red top, and brome grass. with particular reference to the relation... (Abstract.) Amer. Soc. Anim. Prod. Proc. 32: 375-376.

_______, and Purdy, T. L.
1941. pasture studies. XXII. dry matter defecation as an index of forage intake by grazing steers. Sci. Agr. [Ottawa] 22(4): 242-249, illus.

Data obtained by means of feces collection sacs yielded a quantitative record of the daily dry-matter defecation throughout the season of two steers freely grazing an acre of experimental pasture land, and indicated either that there was a seasonal trend in forage consumption or a marked change in the digestibility of the herbage consumed at different times during the season; also that animal units were an unreliable basis of comparison in critical tests of the nutritive value of pasturage since size of animal was not correlated with feces dry-matter output and hence with feed intake.

_______, and others.
1957. voluntary intake of forage as a measure of its feeding value. (Abstract.) Jour. Anim. Sci. 16(4): 1056.

From the results of feeding trials with sheep, it was concluded that voluntary forage intake was a measure of rate of digestion and was a more precise criterion of the nutritive value of forage than the total digestible nutrient or crude fiber content.--Herb. Abs.

Croker, Barbara H.

1959. a method of estimating the botanical composition of the diet of sheep. New Zeal. Jour. Agr. Res. 2(1): 72-85, illus.

Fragments of plant cuticle found in the feces were compared with preparations from the leaves of known plants. As the cuticle patterns, as far as studied, are characteristic for each species, the fragments can be used to identify the plants grazed and to estimate the botanical composition of the diet. The results presented in this preliminary study are purely qualitative. The advantage of this method is that it in no way interferes with the normal habits of the animal, and it may be used for any animals grazing on any type of pasture.--Herb. Abs.

Duckworth, J. E., and Shirlaw, D. W.

1958. the value of animal behaviour records in pasture evaluation studies. Anim. Behaviour [England] 6(3/4): 139-146.

From two field trials at the Cockle Park Research Station in 1949-1950, in which data of animal behaviour on different types of sward were compared and related to liveweight gains, it was concluded that animal behaviour records might be of use in pasture-evaluation studies, but that more basic knowledge of the subject was required. In a further trial, an automatic recording apparatus was used with cattle, housed indoors, to investigate relationships between the jaw movements and the intake of wet matter, dry matter and fiber. The results indicated that: (a) high percentages of dry matter and fiber restricted the weight of wet matter consumed; (b) there was a significant negative relationship between the time spent eating and the weight of wet matter consumed, and an indication that the greater weight of wet matter was eaten at a faster rate of jaw movement; (c) the highest speed of eating was associated with herbage with a low content of dry matter and fiber. It is suggested that herbage with a high content of dry matter and a low fiber-content could be palatable and would be consumed in maximum quantities. It is concluded that before records of jaw movements can be used to determine the amount and quality of food consumed, or to indicate the efficiency of grazing, much fundamental research on cattle housed indoors must be undertaken.--Herb. Abs.

Fels, H. E., and others.

1959. herbage intake of grazing sheep in south-western australia. Austral. Jour. Agr. Res. 10(2): 237-247.

Estimates of the intake of pasture organic matter by grazing sheep were made for subterranean clover-dominant and grass (mainly Bromus species)-dominant pasture, at three growth stages. Evidence is presented that sheep grazing pastures with a total N content of 2.5 percent or less select material of a higher-than-average N content, whereas if the N content of the pasture exceeds 3.5 percent there is no such selection.--Herb. Abs.

Forbes, E. B., Elliott, Ralph F., Swift, R. W., and others.
1946. variation in determinations of digestive capacity of sheep. Jour. Anim. Sci. 5(3): 298-305.

In a study of variation in determinations of digestive capacity of sheep, 22 yearling Merino wethers were used as subjects in a digestion experiment with clover-timothy hay as the only feed. The standard deviation of the values determined for digestibility of the nutrients of the hay was reasonably low except with reference to lignin as determined by difference. A table is presented giving the standard errors and the minimum difference required between determinations with 1-10 sheep for odds of significance of 19 to 1. While the number of sheep required per experimental treatment depends on the permissible variability of results, it is concluded that 5 sheep per treatment are a sufficient number for usual purposes if the experimental technique is efficient, and if the sheep have been successfully treated on account of parasites of the alimentary tract.

Harris, L. E., Cook, C. W., and Butcher, J. E.
1958. intake and digestibility techniques and supplemental feeding in range forage evaluation. Agron. Abs.

_______, _______, and _______.
1959. symposium on forage evaluation. V. intake and digestibility techniques and supplemental feeding in range forage evaluation. Agron. Jour. 51(4): 226-234.

King, W. A., Lee, J., Webb, H. J., and others.
1960. comparison of 6- and 10-day collection periods for digestion trials with dairy heifers. Jour. Dairy Sci. 43(3): 388-392.

Lancaster, R. J.
1949. the measurement of feed intake by grazing cattle and sheep. I. a method of calculating the digestibility of pasture based on the nitrogen content of feces derived from the pasture. New Zeal. Jour. Sci. and Technol. 31(1): 31-38.

A series of digestibility trials showed that the relationship between the weight of pasture organic matter consumed by sheep, and the total N excreted in the feces, was almost constant. Based on this observation a method of calculating organic matter digestibility from the concentration of fecal N has been developed.--Auth. sum.

Lesperance, A. L., and others.
1959. development of techniques for evaluating grazed forage. (Abstract.) Jour. Anim. Sci. 18(3): 1173.

In rotational grazing studies, using steers with esophageal and rumen fistulae, the protein content of the grazed herbage decreased by 4.7 percent over a 2-3 week period, while that of crude fiber increased by 4.9 percent. During the grazing period, the percentage of grass in the feed increased and that of clover decreased, indicating that selective grazing was occurring.--Herb. Abs.

Lofgreen, G. P.
1953. the estimation of total digestible nutrients from digestible organic matter. Jour. Anim. Sci. 12(2): 359-365.

A method is presented which permits the calculation of total digestible nutrients (TDN) from the digestion coefficient of organic matter. The method consists of the following steps: Conduct digestion trial on feed or feeds; determine moisture, ash and ether extract on feeds; determine moisture and ash on feces; calculate the digestibility of the organic matter; calculate the conversion factor, F, according to the formula $F = M(.01 + .000125E)$ where M is the percent organic matter in the feed and E is the percent ether extract in the organic matter; and determine TDN by multiplying the digestibility of organic matter in percent by the conversion factor, F. The TDN values determined by the suggested method in 50 digestion trials agreed closely with those determined by the conventional method. The simplicity and time saving features of the method are its important advantages.

Lucas, H. L.
1943. a method of equalized feeding for studies with dairy cows. Jour. Dairy Sci. 26(11): 1011-1022, illus.

A method of equalized feeding is presented which prevents biases in ration comparisons, and simultaneously increases precision by allowing more uniform persistency among animals. The method consists of periodically changing the concentrate intakes of all animals on an experiment regardless of ration, exactly the same percent of their respective initial concentrate intakes. Meanwhile the roughage portion of the ration is maintained constant for each animal. The method may be applied with either the continuous or change-over types of trials. When using equalized feeding and about 20 animals, it would be expected that differences of 3-1/2 to 5 percent could be demonstrated as significant in the continuous trial, and differences of 2-3 percent in the changeover trial.--H. L. Lucas.

McCullough, M. E.
1958. the significance of and techniques used to measure forage intake and digestibility. Agron. Abs.

McDonald, P., and Purves, D.
1957. the estimation of feed intake by sheep on a silage diet. Brit. Grassland Soc. Jour. 12(1): 22-29.

The results of 19 digestibility trials with sheep on different silages have been reported. From these data and from the results of forty other trials with sheep it has been shown that Lancaster's method of calculating feed intake can be applied to silages when the crude protein content is within the range studied (9-24 percent of the dry matter). For silages in this category, no advantage has been found in taking the nitrogen content of the silage dry matter into account in calculating feed intake. The digestibility of crude protein and Lancaster's 'constant' have both been correlated with the crude protein content of the silage dry matter for the fifty-nine trials considered ($r = 0.767$ and $r = 0.452$, respectively). Although it has been found unnecessary to take the protein content of silage into account in calculating dry matter intake when feeds containing 9-24 percent crude protein in the dry matter are used, evidence is presented which indicates that this factor is of considerable importance when herbage of low protein content is fed. The equation, percent digestibility of

$$CP = 91.57 - \frac{314}{\text{percent CP in herbage DM}}$$

which has been derived from the silage data considered, has been found to be valid when compared with the results of trials with fresh herbage and well preserved hays of low protein content. The results of this work indicate that Lancaster's method is a suitable one for estimating the feed intake of animals engaged in self feeding of silage, provided the silage has been well preserved.

Morgan, A., and Beruldsen, E. T.
1931. sampling technique as applied to irrigated pasture in regard to botanical composition and carrying capacity under different grazing systems. Victoria Dept. Agr. Jour. 29: 36-45.

A method determining, by sampling technique, the effect on (a) productivity and (b) botanical composition of an irrigated pasture, of a system of rotational grazing as compared with a nonrotational system, is suggested. A method of determining, by an extension of the sampling technique described, the amount of herbage consumed per sheep per day is put forward. By a comparison of the percentage of each major species present on the 1/12 acre plots before and after grazing, provided the statistical standards for significance of the differences are satisfactory, the species-preferences of the sheep under the two grazing systems may be deduced, compared, and correlated with factors external to the pasture.--Herb. Abs.

Norris, J. J.
1943. botanical analyses of stomach contents as a method of determining forage consumption of range sheep. Ecology 24(2): 244-251.

Botanical analyses of the stomach contents of 19 sheep were made to determine the accuracy of the method as a measure of the diet of grazing animals. The sheep were starved 24 hours, fed weighed amounts of various forages, slaughtered and the stomach contents removed. The contents were washed, screened, dried, and a sample of 2 percent of the total was analyzed. Recognizable particles of each forage were picked out and weighed to determine the percentage by weight of each species. Fragmentary material, too small to warrant separation, was grouped as unseparated material. The amount of each forage found in the stomach was then compared with the amount in the ration as a test of accuracy. Wide variability between the amount of each forage fed to the animals and the amount found in the stomach throws considerable doubt upon the value of stomach analyses as a quantitative measure of diet of grazing animals. Varied amounts of material from previous feedings remain in the stomach and confuse the analyses. Differentials in the digestibility of different forages and variations in the digestive abilities of sheep were found. From a qualitative standpoint, stomach analyses show some promise and may be used, in connection with other methods of food-habit studies, to compile lists of plant species eaten by grazing animals. However, the results throw great doubt upon the accuracy of the method as a means of determining the actual amount of each forage making up the diet of ruminants. Chemical analysis of stomach contents compared to that of forage consumed showed results even more variable than those from botanical analysis and it is doubtful if this method is of any value as an index to the composition of the diet of grazing animals.--Biol. Abs.

Reid, J. Thomas, and Kennedy, W. Keith.
1956. measurement of forage intake by grazing animals. Seventh Internatl. Grassland Congr. Proc. 1956: 116-121.

The various techniques which have been developed to determine forage intake are discussed. Refinement of the methods for sampling feces followed by evaluation of other materials as external indicators offer the most promise for improving the accuracy of measuring forage intake by grazing animals.

Schneider, Burch H., and Lucas, Henry L.
1950. the magnitude of certain sources of variability in digestibility data. Jour. Anim. Sci. 9(4): 504-512.

A compilation of published digestibility data was studied statistically. Total error within-feed variance may be divided roughly as follows: 25-45 percent is associated with variations in proximate

composition, 20-40 percent is associated with authors, 20-35 percent with samples, and 10-25 percent with trials. Variability in digestibility of a given nutrient tends to be inversely related to the percent of that nutrient in the feed. Especially high variances were noted for digestibilities of ether extract, of crude protein in certain roughages, and of crude fiber in concentrates. Digestibility "by-difference" gave much higher values for certain components of variance than did the method in which feeds are fed alone. Certain species of animals digest certain nutrients more variably than do others. It is concluded that average digestion coefficients should be adjusted for proximate composition in applying them to particular samples. It is suggested that a greater portion of the variance could be related to feed composition if nutrients other than those in proximate analyses were considered. It is also concluded that accurate average digestibility data can only be obtained if a feed is studied by a relatively large number of authors, each investigating several samples of that feed. Only two or three trials need to be made per sample. Coordinated and cooperative studies would seem to be the best means of attaining this end.

Schneider, Burch H., Lucas, Henry L., Pavelch, Helen M., and others.
1950. the value of average digestibility data. Jour. Anim. Sci. 9(3): 373-379.

Using published data for five classes of feeds (hays, other dry roughages, green soiling crops, silages, and concentrates) fed to four species of animals (cattle, sheep, goats, and swine), the value of average digestibility data in the assessment of the nutritive value of particular samples has been studied by statistical methods. The criterion of value used was the ratio of the between- and within-feed variances for digestion coefficients and TDN. The ratio measures the relative increase in precision with which nutritive value is assessed if one uses separate digestion coefficients for each kind of feed as compared to disregarding digestibility or assuming that all feeds in a class have the same average digestibility. The increases in precision if separate digestion coefficients are used may be expected to be moderate to marked for almost all nutrients in all feeds. If digestibility is adjusted for proximate composition, the increases in precision may be expected to be reduced but nevertheless remain substantial. It was not possible to examine the effects of nutrients other than those included in proximate composition. It was concluded that the practice of applying average digestion coefficients for a given feed to particular samples of that feed is warranted, despite the fact that a high within-feed variability is very common.

Staples, George E., and Dinusson, W. E.
1951. a comparison of the relative accuracy between seven-day and ten-day collection periods in digestion trials. Jour. Anim. Sci. 10(1): 244-250.

Comparisons of standard deviations and losses in efficiency of apparent digestion coefficients calculated from data obtained from trials with steers involving 7- and 10-day collection periods showed a comparable degree of accuracy, the short period showing an efficiency loss of less than 1.1 percent for all nutrients tested except N-free extract with 6.83 percent loss. The significance of the larger loss in efficiency for N-free extract is difficult to interpret as the conventional method of N-free extract determination for roughages is admittedly poor.

Swift, R. W., and Bratzler, J. W.
1959. a comparison of the digestibility of forages by cattle and by sheep. Pa. Agr. Expt. Sta. Bul. 651, 5 pp.

B. FACTORS AFFECTING FORAGE INTAKE AND DIGESTIBILITY

Andersen, P. E., Reid, J. T., Anderson, M. J., and others.
1959. influence of level of intake upon the apparent digestibility of forages and mixed diets by ruminants. Jour. Anim. Sci. 18(4): 1299-1307.

Cook, C. Wayne, and Harris, Lorin E.
1950. the nutritive value of range forage as affected by vegetation type, site, and state of maturity. Utah Agr. Expt. Sta. Bul. 344, 45 pp., illus.

During the summer grazing season of 1946, sheep range in the mountains of northern Utah was studied to determine the effect of vegetation type, site, and stage of growth on the nutritive value of range forage. Vegetation types and sites were divided into favorable and unfavorable sagebrush sites and favorable and unfavorable aspen sites. It was found that site conditions and stage of growth were important factors affecting the nutritive content of range forage. Sites indirectly affected the chemical content of plants and plant parts through soil and plant development, water runoff, intensity of shade, and other environmental factors. Plants growing on aspen areas had a higher content of protein, P and ash than plants growing on sagebrush areas. There was little difference in the C content of plants or plant parts on aspen types compared to sagebrush types. Unfavorable sites generally produced a higher cellulose to lignin ratio than favorable sites, and this relationship was true for aspen compared to sagebrush types. Vegetation type did not appear to influence crude fiber content to any marked degree. However, aspen types favored a more rapid seasonal increase in crude fiber than sagebrush types. There was no decided seasonal change in N-free extract and other carbohydrates. The relative amounts of stem and leaf produced accounted for some of the differences in chemical composition between species, and likewise for some of the seasonal changes in composition of the various plants. Evidently the nutrient content of the forage is influenced by many interdependent factors, and the result is the additive of mass effect of all factors operating simultaneously.--C. W. Cook.

________, Stoddart, L. A., and Harris, Lorin E.
1953. effects of grazing intensity upon the nutritive value of range forage. Jour. Range Mangt. 16(1): 51-54.

During the winter grazing seasons of 1949 to 1952, digestion studies were conducted on typical saltbush ranges of Utah to evaluate the factors affecting the nutritional value of the foraging animal's diet. As the degree of utilization increased, the content of the

more desirable nutrients in the available forage decreased, and, in addition, the digestibility of these nutrients was lowered markedly. With intensive utilization the animals were forced to consume the less nutritious portions of the plants and as a result the available nutrients frequently were not adequate to meet the demands of the grazing animals.--C. W. Cook.

Crampton, E. W.
1937. the relation of the lignin and cellulose content of pasture herbage in its nutritive value. Amer. Soc. Anim. Prod. Proc. 1937: 351.

Data are available to show that there may be no constant relation between any constituent of the commonly used feeding stuffs analysis and the live-weight gains made by rabbits fed on diets consisting of clipped, dried pasture herbage. It is postulated that lignification is an important cause of the decrease in feeding value of pasture herbage during adverse seasons, and that the failure of the analysis consistently to predict the feeding value of such forage is partly due to the fact that it does not partition the fat-nitrogen-ash-free fraction according to its chief biologically significant groups.

_______, and Forshaw, R. P.
1939. pasture studies. XV. the intra-seasonal changes in the nutritive value of pasture herbage. Sci. Agr. [Ottawa] 19(12): 701-709.

The limitations of the standard feeding-stuffs analysis as an indication of the feeding value of pasture herbage as measured by the growth of rabbits is shown. The modified feeding-stuffs analysis as proposed by Crampton and Maynard is used in an attempt to explain the observed changes in nutritive value. A progressive decline in growth promoting value and digestibility of herbage from spring until midsummer and a complete recovery in both respects in the fall grown material is noted. It is seen that marked differences in nutritive value may exist between herbage representing only 10 days growth according to the period of the season in which it is grown. The effect of small increases in lignin upon the digestibility of the various feed fractions would indicate that it is not only the amount, but also the mode of deposition, of lignin that determines the extent of its effect upon digestibility and nutritive value of pasture herbage.

_______, and Jackson, I. R. C.
1944. pasture studies. XXVI. seasonal variation in chemical composition of pasture herbage and the relation to its digestibility by steers and sheep. Jour. Anim. Sci. 3(4): 333-339, illus.

Improvement in nutritive value has been claimed for different treatments in many pasture studies on the basis of a resulting increase in protein and/or decrease in fiber content of the herbage. In the light of the data here presented, such conclusions are unwarranted. Neither of these proximate principles differs significantly in its digestibility from each other or from that of the total dry matter. Furthermore, changes in either fraction during the season are either not correlated at all, or are correlated contrary to expectation with the concomitant changes in the digestibility of the dry matter eaten. There appears to be a characteristic steady decline in the digestibility of pasture herbage dry matter from values of the order of 75 percent for early spring grass to 60 percent some 6 weeks later. Digestibility from this time on may rise again, further decline, or remain at the midsummer level, apparently not depending on chemical changes indicated by standard feeding-stuffs analysis or its modifications herein described, but closely paralleling local climatic conditions of moisture and temperature.

Garrigus, W. P., and Rusk, H. P.
1939. some effects of the species and stage of maturity of plants on the forage consumption of grazing steers of various weights. Ill. Agr. Expt. Sta. Bul. 454, 68 pp., illus.

The development of a satisfactory sack and harness for collecting the feces of a freely-grazing steer has made it possible to utilize the predetermined relationships between dry-matter consumption and dry-matter defecation for measuring, with a probable accuracy of 94-97 percent, the forage consumption of a steer grazing at will on uniform forage. The forage intake of each steer was related to the calculated amount of that particular forage required to maintain the steer's energy balance. The actual consumption by the various steers grazing on the different forages, expressed in terms of percentage of maintenance requirement, was: 5-week-old Kentucky bluegrass, Poa pratensis, 270 percent, average of 5 experiments; quarter-bloom red clover, Trifolium pratense, 237 percent, average of 4 experiments; mature red clover, T. pratense, 224 percent, average of 4 experiments; ground reed canary grass, Phalaris arundinacea, 182 percent, average of 4 experiments; late bromegrass, Bromus inermis, 139 percent, average of 4 experiments; and full-bloom alfalfa, Medicago sativa, 129 percent, average of 5 experiments. There was no significant difference in the digestibility of the dry matter from red clover in the two stages of maturity nor in the rates with which they were consumed. No definite relationship was found between size of steer and rate of consumption. An accurate check on the generally-accepted clipping method revealed an apparently inherent error of 57 percent.

Groenewald, J. W., Myburgh, S. J., Laurence, G. B., and others.
1950. digestibility of lucerne hay with special reference to experimental technique in digestion trials. Onderstepoort Jour. Vet. Sci. and Anim. Indus. 24(1/2): 67-86, illus.

Five steers were used to determine the digestion coefficients of dry matter, crude protein, and crude fiber of alfalfa hay during five separate feeding periods. The period has no influence on the coefficient of crude protein but there is some evidence of a period influence on the coefficients of digestion of dry matter and crude fiber.--Auth. sum.

Raymond, W. F., Eyles, Dudley E., and Caukwell, V. G.
1949. cold storage of pasture used in digestibility experiments. Brit. Grassland Soc. Jour. 4(2): 111-114.

Possible errors and difficulties found in the conventional digestibility trials with cut herbage are considered. A method, in which sufficient herbage for a complete digestibility experiment is cut and sampled on one day, and then stored at 0° F., is described. The frozen grass, after thawing, is readily eaten by sheep, and has caused no digestive disturbances in our experiments, except in the case of one sheep, which scoured for a few days during one feeding trial. The dry matter digestibility figures obtained from these experiments show a good agreement between animals. Freezing affects the dry matter and total nitrogen content of herbage by less than one percent, as compared with figures obtained by immediate oven-drying. The possible effects of freezing on digestibility are being investigated.

_______, Harris, C. E., and Harker, V. G.
1953. studies on the digestibility of herbage. I. technique of measurement of digestibility and some observations on factors affecting the accuracy of digestibility data. Brit. Grassland Soc. Jour. 8(4): 301-314.

Details are given of the digestion equipment and technique used in a study of the digestibility of cold-stored herbage. The techniques of dry matter determination and chemical analysis used are described. Factors affecting the accuracy of digestibility data, including the duration of the feeding period and the number of animals used, are considered. Digestibility data on herbage are likely to continue to be of much value until more knowledge on the measurement of the nutritive value of herbage is obtained.

_______, _______, and _______.
1953. studies on the digestibility of herbage. II. effect of freezing and cold storage of herbage on its digestibility by sheep. Brit. Grassland Soc. Jour. 8(4): 315-320.

The effect of freezing and cold storage of fresh herbage at 0° F. has been studied in four experiments. The first two experiments indicated a small drop in the digestibility of herbage after cold storage. Later experiments indicated that these first comparisons

might not be strictly valid, and showed that there was no significant change in the digestibility by sheep, of the dry matter, organic matter and nitrogen in herbage during cold storage.

Raymond, W. F., Harris, C. E., and Kemp, C. D.
1954. studies in the digestibility of herbage. V. the variation with age, of the ability of sheep to digest herbage, with observations on the effect of season on digestive ability. Brit. Grassland Soc. Jour. 9(3): 209-220.

A number of experiments have been conducted, using frozen herbage, hay, and dried grass, to compare the digestive abilities of sheep of different ages. Because of unequal numbers of age-groups and sheep in different experiments, a combined statistical analysis of all the data has not been practicable, but a trend showing digestive ability to increase with age has been found. Regression analysis on the data showed an average increase of about one unit of digestibility per year from lambs to 2-year-olds. An increase in digestive efficiency with age was not found in all the experiments and the data are inadequate to allow digestibility data based on one age-group to be compensated for use with another age-group. It has not been possible in the present experiments to show which fractions of herbage feeds are more efficiently digested by older animals. To study whether the digestive efficiency of individual sheep increased with age, digestion experiments with the same sheep were carried out at intervals during the year on the same feed. While these also indicated an increase in digestive efficiency with age, they pointed to a possible seasonal cycle in digestive ability. These data, together with those from other sources, have suggested that the digestive efficiency of sheep decreases during the winter and rises during the following summer. The possible interrelation with fluctuations in rumen flora content is noted.

________, ________, and ________.
1955. studies in the digestibility of herbage. VI. the effect of level of herbage intake on the digestibility of herbage by sheep. Brit. Grassland Soc. Jour. 10(1): 19-26.

Published data suggest that while the digestibility of concentrates and mixed rations decreases with increase in level of feeding, no such effect is found with dried roughages. Little evidence is available on the effect of level of feeding on the digestibility of bulky fresh feeds. As the level of herbage intake in the field is generally higher than that possible in digestibility experiments, it is important to know whether level of intake has any effect on herbage digestibility. To study this effect six experiments were carried out in which frozen herbage was fed. The first of these was a cross-over trial, while in the remaining five, two groups of similar sheep were fed simultaneously at LOW and HIGH levels of

intake (approximately 80:100). A decrease in dry-matter digestibility (percent) with increase in level of herbage intake was found in all the experiments. This was 0.1 in Experiment 1, and varied from 0.3 to 2.7 in the remaining experiments, with a weighted average of 1.06. It is suggested that a similar difference in digestibility between HIGH levels of indoor feeding and field intake levels is likely. This is probably small in comparison with other errors in many experiments, but needs to be considered in more critical experiments. Net utilization of herbage feeds is likely to decrease more than digestibility as level of feeding is increased. The importance of avoiding selective feeding in digestibility studies of this type is discussed.

Tayler, J. C.
1959. a relationship between weight of internal fat, "fill," and the herbage intake of grazing cattle. Nature [London] 184(4704): 2021-2022.

Anthony, W. Brady, Parks, Paul F., Mayton, E. L., and others.
1958. evaluation of pasture swards by determining through use of chromogens-chromic oxide the seasonal variations in dry matter intakes and digestibilities by yearling beef steers. (Abstract.) Jour. Anim. Sci. 17(4): 1207.

Chromic oxide and plant chromogens techniques were used in combination to estimate forage digestible dry matter intakes of yearling steers grazing swards of lespedeza sericea (LS), white clover-dallis (CID), alfalfa-orchard (AO) and crimson clover-coastal bermuda (CrCo). Intake measurements were made at 28-day intervals for complete grazing seasons. For the first test year, average daily digestible dry matter intakes for the entire grazing season were 8.68, 8.16, 8.89 and 6.77 lb., respectively, for LS, CID, AO and CrCo swards. For the second test year, comparable values were 8.69, 9.54, 8.95 and 8.11. For the first test year, accumulated season totals of digestible dry matter consumed per acre for the several swards were appreciably different from per acre totals of TDN calculated by use of constants for maintenance and live weight gain. The two measures resulted in almost the same acre values for the second test year and either method might have been used for estimating effective nutrient yields for the several swards. Forage protein digestibility data (selective grazing bias in all values) revealed relative significant inferiority of LS protein. Cattle grazing LS consistently excreted relatively large amounts of fecal protein. Digestibility coefficients were lowest for LS.

_______, and Reid, J. T.
1958. methoxyl as an indicator of the nutritive value of forage. Jour. Dairy Sci. 41(12): 1715-1722.

Studies were made to determine the relationship between the digestibility of dry matter and the fecal methoxyl content, and between the digestibility of forage and its methoxyl content. Different grass/legume mixtures were used as forage, either grazed, or cut and fed at different stages of maturity. The coefficients of digestibility of the cut forage were determined by conventional digestibility trials and those of the grazed forages by the chromogen technique. The digestibility of the dry matter of cut forage was highly significantly correlated ($r = -0.83$) with its methoxyl content. The methoxyl content of forage appeared to be of use as an index of relative digestibility for selecting between similar forages of widely differing digestibility.--Herb. Abs.

Archibald, J. G., Owen, D. F., Jr., Fenner, H., and others.
1958. comparison of chromium ratio and lignin ratio techniques for determination of digestibility of hays. Jour. Dairy Sci. 41(8): 1100-1103.

Digestion coefficients for dry matter, protein, energy, crude fiber, and N-free extract from 16 individual trials show that the chromium trioxide method for determining digestibility of forages gave somewhat more uniform results than did the lignin method, as indicated by generally lower standard errors of the mean values.--Auth. sum.

Bradley, N. W.
1959. an evaluation of chromic oxide as an indicator for digestibility of beef cattle rations. Diss. Abs. 19(11): 2704.

_______, Forbes, R. M., Albert, W. W., and others.
1958. use of the chromic oxide method for determining digestible energy and protein in complete pelleted steer rations. (Abstract.) Jour. Anim. Sci. 17(4): 1199.

Chromic oxide excretion patterns of 6 steers were compared when indicator was administered by capsule or orally as a part of a complete pelleted ration fed at 8 a.m. daily during twelve, 24-hour collection periods for each method, with fecal collections being made at 2-hour intervals. The chromic oxide concentration in the individual fecal samples, expressed as a percent of the mean 24-hour concentration, varied from 57 to 208 percent when administered by capsule but only from 73 to 155 percent when administered in the pelleted ration. The general shape of the two excretion patterns was similar. Eight steers, fed the complete pelleted ration with indicator at 8 a.m. daily, were used in a 7-day collection period to compare the total collection method with the 8 and 10 a.m. composited grab sampling method. Apparent digestion coefficients for energy were 71.96 $\pm$ 3.40 and 72.6 $\pm$ 3.17 and for protein 71.60 $\pm$ 3.18 and 71.88 $\pm$ 3.19, respectively, for the 2 methods. The reduction in variability in chromic oxide excretion in the pelleted ration method of administration and the similarity in the apparent digestion coefficients determined by total collection and by 8 and 10 a.m. composited grab samples would suggest a simple method for determining the digestibility of total dry matter or of individual nutrients in beef cattle rations under practical feed-lot conditions.

Brisson, G. J., and Pigden, W. J.
1958. chromic oxide in a sustained-release pellet to reduce variation in its diurnal excretion pattern in cattle. (Abstract.) Jour. Anim. Sci. 17(4): 1200.

Chromic oxide (Cr_2O_3) was given in pellet form (1/2 Cr_2O_3 + 1/2 Kerr's plaster + water) once per day at 4 p.m. to two steers (E-1) and two cows (E-2). Fresh grass was fed at 7 a.m. and 4 p.m. Rectal samples were taken at regular intervals for 5 and 7 consecutive days in E-1 and E-2, respectively. The Cr_2O_3 concentration expressed as percent of the respective daily mean concentration was 100.3 $\pm$ 2.5 at 7 a.m., 95.3 $\pm$ 2.4 at 10 a.m., 96.5 $\pm$ 2.6 at 1 p.m.,

100.5 ± 2.5 at 4 p.m., 100.8 ± 1.7 at 7 p.m., 102.4 ± 1.9 at 10 p.m., 100.2 ± 1.73 at 1 a.m., and 99.0 ± 1.53 at 4 a.m. The small differences between these concentrations were not statistically significant by analysis of variance. Total recovery measured only in E-1 was 100.4 percent for a period of 14 days preceding the rectal sampling period. There was no regurgitation of the pellets in either E-1 or E-2.

Davis, C. L., Byers, J. H., and Luber, L. E.
1958. an evaluation of the chromic oxide method for determining digestibility. Jour. Dairy Sci. 41(1): 152-159, illus.

Eight lactating dairy cows were used in a 10-day digestion trial, in which the conventional total collection method of determining digestibility was compared with the grab-sampling technique using chromic oxide as an indicator. Variations in the excretion of chromic oxide and crude fiber at 2-hour intervals over a 24-hour period were studied. Statistical analysis showed no significant differences between the two methods of determining the digestibility of the rations. Analyses of samples from the total fecal composites for the first six days of the 10-day trial revealed coefficients of digestibility comparable to those obtained for the entire period. Considerable variations were found in the chromic oxide content of the feces samples taken at various hours of the day, regardless of whether chromic oxide was administered once or twice daily. These variations make it difficult to select a sampling period which will give approximately 100 percent recovery for all cows for a given day; however, these data indicated this can be overcome in digestion studies by sampling the feces for a 10-day period. The hourly variations in the excretion of chromic oxide were not associated with the excretion of crude fiber.--Auth. sum.

Elam, C. J., Putnam, P. A., and Davis, R. E.
1958. the fecal excretion pattern of chromic oxide when administered to hereford heifers in a completely pelleted ration. (Abstract.) Jour. Anim. Sci. 17(4): 1199-1200.

Chromic oxide (Cr_2O_3) was mixed uniformly into a pelleted ration at 0.5 percent and fed to three Hereford heifers per treatment. Treatments were: (1) limited-fed once daily (LOD), (2) full-fed once daily (OD), (3) full-fed twice a day (TD), and (4) ad libitum (AL). After a 9-day preliminary period, fecal samples were collected at 3-hour intervals for 48 hours. Dry matter and Cr_2O_3 analyses indicated that a significant ($P < 0.05$) time-concentration variation occurred in fecal Cr_2O_3. Furthermore, Cr_2O_3 excretion was influenced by the different feeding schedules. Respective peak concentrations of Cr_2O_3 expressed as percent of daily mean, and times at which the the peaks occurred were as follows: (1) LOD, 112 percent at 9 p.m., (2) OD, 108 percent at 12 a.m., (3) TD, 111 percent at 3 p.m., and

(4) AL, 109 percent at 9 a.m. The magnitude of the variation in fecal Cr_2O_3 concentration, exhibited during a 24-hour period, precludes the indiscriminate sampling of feces for digestion trials as regards time. However, it is thought that the individual variation exhibited by different animals fed Cr_2O_3 in pellets is less than when administered in gelatin capsules. The extremes found in individual observations in this experiment were low, 74 percent and high, 135 percent. Four beef steers were fed (TD) a predominantly roughage ration which was ground, mixed with Cr_2O_3 and pelleted. Analyses of feces samples collected in the morning and afternoon for 8 days resulted in Cr_2O_3 concentrations which tended to support the type of excretion pattern found in the twice a day feeding.

Forbes, R. M.
1950. protein as an indicator of pasture forage digestibility. Jour. Anim. Sci. 9(2): 231-237.

A method of calculating dry matter digestibility of forages from the protein content and predicted protein digestibility is presented. The data obtained are compared with data obtained by conventional and by lignin-ratio methods of determining digestibility. The average digestibilities calculated in the various ways from data of lamb and steer trials are, in general, similar, but the slopes of the regressions of dry matter digestibility on lignin content are generally less when data are obtained by the "protein digestibility" method. This difference in slopes is statistically significant only in the case of the lamb trials. It would appear that the method may be used with a satisfactory degree of accuracy for the determination of digestibility of dry matter by grazing steers. A difference in digestive capacities of cattle and sheep has been demonstrated; sheep are apparently more efficient digesters of protein in low-protein forage than are cattle. The difference disappears above 15 percent protein in the dry matter of the forage.

Glover, J., and Duthie, D. W.
1958. the nutritive ratio/crude-protein relationships in ruminant and non-ruminant digestion. Jour. Agr. Sci. [England] 50(2): 227-229, illus.

In both ruminant and non-ruminant digestion, the nutritive ratio of a feed is shown to be very significantly related to the crude-protein content of that feed. This confirms that there is a relationship between the total crude protein and digestible protein in a ruminant feed, and strongly suggests that there should also be a relationship between these two components in non-ruminant feeds.--Auth. sum.

Hardison, W. A.
1957. indicator techniques with cattle, their usefulness and shortcomings. (Abstract.) South. Pasture and Forage Crop Impr. Conf. Rpt. 14: 30-31.

Holter, J. A.
1959. the use of forage and fecal protein as indicators of forage digestibility. Diss. Abs. 20(6): 1934-1935.

_______, and Reid, J. T.
1959. relationship between the concentrations of crude protein and apparently digestible protein in forages. Jour. Anim. Sci. 18(4): 1339-1349.

In a study of the relationship between the concentration and digestibility of crude protein in forages from a wide range of plant species harvested at various stages of growth and in different ways, and fed to sheep and cattle, an exponential relationship was found between apparent protein digestibility and the crude protein concentration, while a positive rectilinear relationship existed between percentage crude protein and percentage digestible protein. Forage constituents appeared to be interrelated in such a way that excretion of metabolic N by livestock was correlated with the concentration of crude protein in the forages. The true digestibility of protein appeared to be relatively constant regardless of the crude protein concentration in the forages. It was found possible to predict the digestible protein content of 4 grasses heavily fertilized with N, or that of lucerne leaf- or stem-material, with a high degree of accuracy by means of the formula: percentage digestible protein = percentage crude protein X 0.929 - 3.48.--Herb. Abs.

Kivimae, A.
1959. chemical composition and digestibility of some grassland crops. Acta Agr. Scand. [Sweden] Sup. 5, 142 pp.

The results are presented of an extensive series of analyses made during 1947-1955 on lucerne, red clover, alsike clover (<u>Trifolium hybridum</u>) and timothy, grown in Southern Sweden. Data are given of climatic conditions during the trial period, crop phenology, experimental methods and experimental errors. The main section of the paper is devoted to the chemical composition and nutritive value of the crops during the growing season and equations of the regression of growth stage on the contents of dry matter, crude protein, ether extract, redose, inredose and redosan, N-free extract, crude fiber, cell-wall constituents, cellulose, lignin, carotene, ash, Ca, P and Ca/P ratio. Further data are given on differences between the chemical composition of tetraploid red clover varieties and Ultuna diploid red clover, between first- and second-cut red clover, red clover and alsike clover and the relationships between the contents

of different constituents in the crops during the growing season. The chemical composition of the crops at four growth stages are given, with figures for the average composition and the standard deviation, as a means for evaluating the accuracy of crude fiber-, lignin-, and protein-contents and stage of growth, as indices for estimating the nutritive value and digestibility of forages and, to a lesser degree, their chemical composition. Protein gave the best results as an indicator substance, followed closely by crude fiber, though the accuracy of estimation depended on the closeness of the correlation between the indicator substances and the substance it was used to estimate. There are further sections on seasonal and diurnal changes in chemical composition, on the digestibility of the crops, and on the digestibility of hays from Northern Sweden, with particular reference to the value of indicator substances for estimating digestibility.--Herb. Abs.

Lambourne, L. J.
1957. measurement of feed intake of grazing sheep. I. rate of passage of inert reference materials through the ruminant digestive tract. Jour. Agr. Sci. [England] 48(3): 273-285.

Feces output for sheep varied from 100 to 400 g. air dry weight daily. Feed intake computed from below 400 g. to 1900 g. air dry weight daily. Markers appeared in feces 5 to 8 hours after dosing. Peak values at 10 to 18 hours fell off until 60 to 70 hours when markers could no longer be reliably identified.

Miller, W. J., Donker, J. D., Mahaffey, J. C., and others.
1957. the effect of feeding frequency, type of roughage and method of administration on the diurnal excretion of chromic oxide, chromogens, nitrogen, dry matter and ash. Ga. Agr. Expt. Sta. Tech. Bul. (n.s.) 14, 20 pp.

Minson, D. J.
1958. the errors involved in the measurement of herbage consumption using indicator technique. Ph.D. Diss. Univ. Reading 1958, 215 pp., illus.

A study was made of the cause of the large standard error of the estimate of fecal index regression equations. Between 80 and 90 percent of the variation was shown to be caused by differences in the type of herbage fed, the remaining variation equal to about $\pm$ 1 digestibility unit being associated with animal variation and analytical error. When fecal index regression equations, derived indoors, are applied to field conditions additional errors are introduced by differences in level of feeding, internal parasites, and type and age of animal used. A new method for estimating the digestibility of grazed herbage "the combined method" is suggested. The use of chromic oxide for estimating the fecal production of grazing

animals is considered and a method for obtaining a representative sample of feces direct from the sward is described.--Herb. Abs.

Minson, D. J., and Raymond, W. F.
1958. sources of error in the use of fecal index relationships. Hurley Grassland Res. Inst. Expt. Prog. 10: 92-96.

Pigden, W. J.
1956. indicator methods for measuring herbage consumption. nitrogen as an internal indicator and its distribution in feces of grazing cows. Canada Expt. Farms, Prog. Rpt. (1950-1954): 34-35.

Samples of feces from each of 3 dairy cows grazing high-quality pasture were taken every 2 hours from 8.0 a.m. to 8.0 p.m. and at midnight and 4.0 a.m. "No differences in fecal concentration of N were observed between sampling hours or between animals. However, differences were observed between days. Thus, it appears that when N is employed as an internal indicator for high-quality pastures, fecal samples can be taken from cows any time during the day, but should be taken each day in order to obtain samples that are truly representative of a given period. Further studies are in progress to determine if the same considerations apply to medium- and low-quality pastures." The constant 92, calculated from digestibility, and used in the formula for determining organic-matter digestibility coefficients of consumed herbage is higher than the constant obtained by Lancaster, viz. 83, and supports results of previous workers.

Putnam, P. A., Loosli, J. K., and Warner, R. G.
1958. excretion of chromium oxide by dairy cows. Jour. Dairy Sci. 41(12): 1723-1729.

Raven, A. M., and Robinson, K. L.
1957. studies in the determination of the digestibility of perennial ryegrass. 1. the determination of digestibility and retention of nutrients using a conventional method. 2. Digestibility coefficients and food intake as determined by a conventional method and by fecal index methods. North. Ireland Min. Agr. Res. and Expt. Rec. (1955) 5: 53-73.

Raymond, W. F.
1948. evaluation of herbage for grazing. Nature [London] 161(4102): 937-938, illus.

Sheep feces analyzed for dry matter, N, and ash showed that feed intake varied with the size of animal, but not with the grazing available. This differed from mowing-machine estimates; when feed is

short, stock eat below the mowing level; when feed is plentiful the machine overestimates consumption. The N content of feces varied with that of feed, and on a restricted plot declined over a month, due to selective grazing of the leafiest parts first. Fecal N analysis would be a better index of food quality than would analysis of mowed samples.

Raymond, W. F.
1954. studies in the digestibility of herbage. III. the use of fecal collection and chemical analysis in pasture studies (a) ratio and tracer methods. Brit. Grassland Soc. Jour. 9(1): 61-67.

Because of the limitations of cutting techniques and methods based on animal production data for the evaluation of pasture output, methods depending on the collection of feces from grazing animals are being studied. The use of the feed:fecal ratio technique is described. To obviate the need for total fecal collection in the field, chromic oxide may be used as an 'indigestible tracer.' By using chromic oxide and an 'indigestible tracer' present naturally in the herbage, it is unnecessary either to make total fecal collection in the field, or to carry out indoor digestion trials on cut herbage. The errors likely in these techniques are considered. The most serious of these is the need for sampling of the sward for 'herbage as grazed,' either for chemical analysis or for digestion experiments. Errors due to the indigestibility of 'tracers' varying from 100 percent and, to nonrepresentative sampling of feces are discussed. It is considered that techniques being developed which require neither herbage sampling nor the use of 'indigestible plant tracers' may have advantages over the methods discussed in the present paper.

_______, Kemp, C. D., Kemp, A. W., and others.
1954. studies in the digestibility of herbage. IV. the use of fecal collection and chemical analysis in pasture studies (b) fecal index methods. Brit. Grassland Soc. Jour. 9(1): 69-82.

In fecal index methods, relationships between the composition and digestibility of herbage and the chemical composition of the resulting feces are studied. Published data on this are reviewed. Based on data from 40 herbage feeds, ranging in dry matter digestibility from 55.2 to 80.8, regressions have been calculated relating the digestibility of both dry and organic matter in herbage and the fecal contents of nitrogen, macerate crude fiber and chromogen. The use of these regressions in predicting the digestibility of herbage grazed in the field from the composition of the resulting feces is considered. In particular the difference between the standard error of the regression and the standard error of a predicated value is

emphasized. The use of the indigestibility coefficient to calculate herbage intake from fecal production in the field leads to errors higher than those apparent in the original estimate of digestibility. Comparison of the present regressions with those of Lancaster and Reid shows considerable divergences. These are discussed, and seem to emphasize the need for more standardized techniques. The need for a method of obtaining a representative sample of feces in the field is recognized. The fecal index method appears to offer advantages over indigestible tracer techniques. Possible improvements in the method are discussed. Fecal analysis offers valuable information on day-to-day variations in quality of grazing and on the effect of management on degree of selection of herbage.

Raymond, W. F., and Minson, D. J.
1955. the use of chromic oxide for estimating the fecal production of grazing animals. Brit. Grassland Soc. Jour. 10(4): 282-296.

A study of factors affecting the accuracy of the chromic-oxide method for estimating fecal production in pasture studies is reported. The method of analysis for chromium is described. Chromic oxide was shown to have no effect on the digestion of herbage by sheep. A comparison was made of the administration of chromic oxide in gelatin capsules and as a liquid drench. Recovery of chromium in the feces was close to 100 percent with both methods. No reduction in the diurnal variation in the chromium concentration in feces was found by using the drench, in which the chromic oxide particles were of low specific gravity. Fecal chromium oxide concentrations were shown to follow no constant diurnal pattern; the latter varied with a number of factors, including level of herbage intake and possibly herbage digestibility. Thus a system of grab sampling at fixed times can lead to incorrect estimates of fecal production. A method for obtaining a representative sample of feces directly from the grazing sward is described ('ring sampling'). Estimates of fecal production obtained by the 'ring-sampling' method were found to agree closely with those obtained by total collection of feces during complete grazing periods. Variations found in the diurnal excretion patterns of chromic oxide are discussed, and are related to times and method of dosing of the oxide together with variations in rates of passage of feed through the hind tract. The effects of variations in the rate of passage of feed on the daily excretion of chromic oxide in the field are discussed. It appears that fecal production data estimated by the chromic-oxide method may allow more valid estimates of daily herbage intake than do total collection data.

_______, _______, and Harris, C. E.
1959. studies in the digestibility of herbage. VII. further evidence on the effect of level of intake on the digestive efficiency of sheep. Brit. Grassland Soc. Jour. 14(2): 75-77.

Results are reported from six digestibility experiments in which frozen herbage was fed to groups of sheep at HIGH and LOW levels of intake. The sheep on the HIGH level of intake digested the dry matter, organic matter, nitrogen and normal-acid fiber in the herbage less efficiently than those on the LOW level, confirming earlier results reported in Part VI of this series. Evidence suggests that this difference results from the higher rate of passage of food through the digestive tract at the HIGH level of intake. These results are discussed with reference to the errors introduced into the fecal-index method for estimating the digestibility of grazed herbage.

Smith, A. D., Turner, Robert B., and Harris, Grant A.
1956. the apparent digestibility of lignin by mule deer. Jour. Range Mangt. 9(3): 142-145.

Digestion coefficients were calculated for browse species native to Utah and lucerne hay fed to mule deer. Calculations were made by the direct method and by the lignin-ratio technique. No clear conclusions could be drawn as to whether the apparent digestion of lignin was due to inability to isolate it or to actual digestion. The lignin-ratio technique appears to be of doubtful validity on the types of forage used.--From auth. sum.

Squibb, R. L., and others.
1958. comparison of chromogen method with standard digestion trial for determination of the digestible nutrient content of kikuyu grass and ramie forages with sheep. Jour. Anim. Sci. 17(2): 318-321.

Results obtained using the chromogen method and standard digestion trial showed excellent agreement in the case of *Pennisetum clandestinum* but not for *Boehmeria nivea*, where the chromogen method gave low and highly variable results. Both forages were similar to legumes in crude protein (10-16 percent). The TDN content of *P. clandestinum* was 60 percent and that of *B. nivea* about 69 percent. It was concluded that the chromogen method was unsuited for determining the coefficients of digestibility of little-known, or unknown tropical forages.--Herb. Abs.

Vallentine, J. F.
1956. use of indicator methods in range digestion trials. a review. Jour. Range Mangt. 9(5): 235-239.

Woolfolk, P. G.
1957. use of indicator techniques with sheep. (Abstract.) South. Pasture and Forage Crop Impr. Conf. Rpt. 14: 31.

D. ANIMAL PRODUCTION

Blaser, R. E., Bryant, H. T., Ward, C. Y., and others.
1959. symposium on forage evaluation. VII. animal performance and yields with methods of utilizing pasturage. Agron. Jour. 51(4): 238-242.

Davis, R. R., and Bell, D. S.
1958. a comparison of birdsfoot trefoil-bluegrass and ladino clover-bluegrass for pasture. 1. response of lambs. Agron. Jour. 49(8): 436-440.

Mixtures of Italian birdsfoot trefoil (Lotus corniculatus)/Kentucky bluegrass (Poa pratensis) and Ladino clover (Trifolium repens var.)/ Kentucky bluegrass were established on fertile soil in Ohio in 1952. During three trial years the swards were grazed by cross-bred, wether lambs either continuously, or rotationally with grazing periods of 10 to 16 days alternating with rest periods of 24 to 30 days. Stocking rates were adjusted by using grazer and tester animals. During the first grazing year (1953) both swards were predominantly legume. Rainfall deficiency during summer and autumn of 1953 almost eliminated Ladino clover stands. Continuous grazing gradually eliminated stands of birdsfoot trefoil, while swards subjected to rotational grazing still had good trefoil stands after three years. Data are given of observed lamb-days, live-weight gains and daily live-weight gain and TDN consumption of tester animals. Year X mixture interactions were large, showing the need for data from several years to give adequate comparisons between mixtures.--Herb. Abs.

Hedrick, D. W.
1957. rabbits as a tool in pasture and range utilization research. Jour. Range Mangt. 10(4): 180-182, illus.

Some data are given of the results of preliminary trials on the use of rabbits as grazing animals for evaluating pasture productivity. It is thought that rabbits could be of considerable value for providing a number of different degrees of utilization of pasture, without the need to devote large areas to such trials, and that rabbits leave pastures in a condition more nearly approaching that after grazing by livestock, than does clipping.--Herb. Abs.

Hinman, R. B.
1937. live weight gains as a measure of pasture yields. Amer. Soc. Anim. Prod. Proc. 1937: 83-84.

In order to evaluate results of a pasture improvement program properly, live-weight gains on similar animals supply the most accurate and accessible method of measurement. It can be fully appreciated by

the practical mind and is of some value to the experimentalist, until a better method is discovered.

Ivins, J. D.
1953. the measurement of pasture output on the dairy farm. Brit. Grassland Soc. Jour. 8(4): 337-344.

The figures for utilization of starch equivalent from pasture, as a measure of pasture output, have been calculated individually for 382 dairy cows. The data shows considerable variation from animal to animal and bears close relationship to milk production. It is apparent that the time of calving exerts a substantial effect on the rate of utilization of starch equivalent from pasture and that to provide a comparable estimate of pasture productivity it is necessary to apply corrections for time of calving to the figures for utilized starch equivalent.

Kennedy, W. K., Reid, J. R., and Anderson, M. J.
1959. evaluation of animal production under different systems of grazing. Jour. Dairy Sci. 42(4): 679-685.

Lucerne/Ladino clover/smooth brome grass pasture was grazed by dairy cattle under four managements: (a) strip grazing, (b) 3-paddock rotation, (c) 6-paddock rotation, (d) zero (mechanical) grazing. When animals had strip-grazed an area equivalent to that of a paddock, cows under management (b) and (c) were moved. Milk production per acre on (b) was as high as on other treatments. Lucerne stands declined more rapidly on (b) than on (a) or (c), but there was a corresponding increase in the stand of Ladino clover. An excellent lucerne stand was maintained on (d). It was concluded that valid comparisons between grazing systems could not be made unless forage under all treatments was fully utilized.--Herb. Abs.

Knott, J. C., Hodgson, R. E., and Ellington, E. V.
1934. methods of measuring pasture yields with dairy cattle. Wash. Agr. Expt. Sta. Bul. 295, 20 pp.

Because of the lack of uniformity of method in measuring pasture yields with dairy cattle, the total digestible nutrient yield method is recommended. This method measures results under actual grazing conditions and takes into consideration the requirements for gain in live weight, maintenance, and milk production, from which is deducted the nutrient content of supplemental feed consumed. The remainder represents the nutrients derived from pasture. Allowance may also be made for loss in live weight. A standard of total digestible nutrient requirements per lb. of gain in live weight with dairy cows of 3.53 lb. is recommended, and the method of arriving at this amount is explained. An allowance of 2.73 lb. of total digestible nutrients for each lb. of loss in live weight is suggested. For

converting pasture yields into carrying capacity or cow days, it is recommended that 16 lb. of total digestible nutrients be used for a standard cow day. Using the above method, the average yearly yield chiefly of total digestible nutrients for a pasture mixture under continuous grazing was 5,498.5 lb., for the same mixture under rotational grazing 5,985.7 lb., for a reed canary grass pasture 5,253.6 lb., and for a wheat pasture 1,875 lb. per acre. The standard cow days were 343.6, 374.1, 328.4, and 117 for the respective pastures. --Biol. Abs.

Morrison, H. B., and Ely, Fordyce.
1941. calculating pasture yields with dairy heifers as experimental animals. (Abstract.) Jour. Dairy Sci. 24(6): 515-516.

Baker, A. L., Phillips, Ralph W., and Black, W. H.
1947. the relative accuracy of one-day and three-day weaning weights of calves. Jour. Anim. Sci. 6(1): 56-59.

A study of weights taken on 178 calves immediately before weaning time, when they averaged about 232 days of age, has shown that there is no advantage in taking weights on 3 days, over taking a single weight, when uniform conditions for the calves were maintained. Calves lost some weight during the 3 days, the respective average daily weights being 425.9, 425 and 422.9 on successive days. The 3-day average of 424.6 did not differ significantly from the weight taken on the first day. After dividing into weight classes, with 20-lb. intervals, the standard errors of single and 3-day weights were compared. In 14 classes having 4 to 23 animals each, the standard error was lower in the first-day weights in all classes than in the second- and third-day weights and in the 3-day average. The standard error of the second-day weights was lower than that of the third-day weights in 9 of the 14 classes.--R. W. Phillips.

Baker, G. A., and Guilbert, H. R.
1942. non-randomness of variations in daily weight of cattle. Jour. Anim. Sci. 1(4): 293-299, illus.

Statistical analyses are presented for 69 consecutive daily weighings of 8 head of yearling cattle. During the first half of the period the animals had free access to feed and water and were weighed at 11:20 a.m.; during the last half, water was shut off at 7:00 p.m. and the cattle weighed before 6:45 a.m. The analyses confirm the report of Maymone and Sircana (1930) that cyclic variations may occur in the day-to-day deviations of cattle weights. Three daily weights of 14 animals would be required to obtain the accuracy assumed for 3 daily weights, independent in a probability sense for 10 animals. Some correlation exists between deviations of the various animals due to environmental conditions. When the animals were allowed free access to water and the weighings were made near mid-day, the deviations in daily weights were positively correlat4d with daily temperature range. When the animals were without feed and water at night and the weights taken early in the morning, no significant correlation between deviations in daily weights and daily temperature range was found. An adequate adjustment period is necessary; shrunk weights lessen environmental effects. A relatively greater increase in accuracy results from using more animals than more weights per animal.--G. A. Baker.

Bean, H. W.
1948. single weight versus a three-day average weight for sheep. Jour. Anim. Sci. 7(1): 50-54.

The data used in this study are the starting and final weights of lambs from 5 annual feeding projects conducted at the Ill. Agr. Expt. Sta. There were 1,335 lambs at the beginning of the experiments. Each lamb was

weighed individually on three consecutive days at the beginning and end of the test. The averages of each of these three weights were considered the experimental weights of the animals. The deviation of the 3-day average from the first day weight was one criterion. The initial experimental weights of 1,300 animals, or 97% of the total, were within the range represented by the first day weight ± 3 lbs. The final experimental weights for 99% of the total lambs were within the range of the first day weight ± 2 lbs. This study also shows that in the initial weights the mean square for the 3-day average is 4.2% less than the mean square for the first day weights, while in the final weights it is 2.1% greater. There is no significant difference between the lot weights obtained on the first day and those obtained from the 3-day averages. The extra work involved in weighing on 3 consecutive days did not result in increased accuracy and therefore did not produce the results for which it was intended. There seems to be no justification for continuing the practice of weighing an experimental animal on 3 consecutive days.--H. W. Bean.

Brothers, Don G., and Whiteman, J. V.
1958. variation in growth rate between selected like-sexed twins as compared to randomly selected like-sexed lambs. (Abstract) Jour. Anim. Sci. 17(4): 1144.

Variances between selected like-sexed twin lambs were compared to variances among randomly selected like-sexed lambs of similar weight to estimate the experimental efficiency obtainable by the use of twins in growth studies. The lambs were all of similar breeding and were raised under similar conditions at the Fort Reno Experiment Station over a 3-year period. Nineteen pairs of male and 13 pairs of female twins within 6, 4 and 2 lb. of each other were selected when they weighed approximately 50 lb. Like-sexed random lambs were also selected within the same weight ranges simultaneously. Average deily gains to marketing, carcass yields and grades were obtained. Twin efficiency values were calculated for these characteristics by the mean square comparisons of among random individuals within pairs of twins. The efficiency values for daily gain were 1.68, 3.70 and 5.42 for males and 2.00, 1.62 and 2.14 for females when pairs were selected within 6, 4 and 2 lb. of each other, respectively. Values for carcass grade were 1.84, 1.70 and 1.51 for males and 6.12, 7.48 and 9.44 for females. For carcass yield the males had values of 1.17, 1.00 and 1.60 for the 6, 4 and 2 lb. selection ranges. The values for females were all less than one. Although quite variable, these estimates indicate selected like-sexed twin lambs may be useful in reducing the experimental error.

Hodgson, R. E., and Knott, J. C.
1942. accuracy of live weights of dairy cows on pasture. Jour. Dairy Sci. 25(2): 161-169.

The experimental error, the standard deviation of daily trends, and the standard error of 3-day initial and final live weights of cows on pasture were determined by analyses of variance. The experimental error

of 46 weight groups was 14 lbs. with a range of from 7 to 28.3 lbs. The standard deviation of day to day trends of the groups of cows averaged 7.7 lbs. with a range from 0.5 to 20.8 lbs. The standard error of the live weights of cows weighing about 1200 lbs. averaged only 2.2 lbs. The experimental error, standard deviation of daily trends, and standard error of the initial and final weights were of about the same order.--R. E. Hodgson.

Ivins, J. D., and Morgan, J. T.
1957. note on the extent and significance of losses in live weight of inwintered cattle on turning out to grass in spring. Brit. Grassland Soc. Jour. 12(1): 19-21.

A trial designed to examine the significance and extent of losses in live weight of inwintered cattle turned out to grass in spring is described. The results obtained for two pairs of identical twin cattle suggest that most of the loss in live weight after a 14-day grazing period could be related to differences in the contents of the alimentary tract.

Koch, Robert M., Schleicher, E. W., and Arthaud, Vincent H.
1958. the accuracy of weights and gains of beef cattle. Jour. Anim. Sci. 17(3): 604-611.

Analysis of the three initial and three final weights of 582 calves for full and shrunk conditions was presented. Shrunk weights were influenced less by fluctuations in fill and were considered a more accurate measure of weights and gains. The use of 3-day average weights was effective in reducing fluctuations in fill. The average of three weights or at least two weights is recommended for use where comparisons of individuals are concerned. Animal differences were large in comparison to residual variation. Adjusting the number of animals to obtain the accuracy needed was the most effective way of reducing variation for comparisons of groups of animals.--Auth. sum.

Koger, Marvin, and Knox, J. H.
1945. the effect of sex on weaning weight of range calves. Jour. Anim. Sci. 4(1): 15-19.

The weaning weights of steer and heifer calves grown under range conditions were observed for a period of 8 years. The mean weights of the 2 sexes corrected for difference in weaning age were 443 lb. for 419 steers and 411 lb. for 444 heifers. Steers were heavier than heifers every year. The difference in favor of steer calves was highly significant. The difference in weight of sexes was tabulated for the offspring of 12 bulls, 10 of which were related. Steers were heavier than heifers for all sires. The sex sire within year interaction was small, indicating that sex differences did not vary significantly among sires.--Marvin Koger.

Manning, H. L., and Williams, E.
1950. a note on the estimation of liveweight of cattle in Uganda. East African Agr. Jour. 16(2): 94-96.

An estimate of weight of Teso cattle with appropriate confidence limits has been derived from a linear regression formula.

Patterson, R. E.
1947. comparative efficiency of single versus three-day weights of steers. Jour. Anim. Sci. 6(3): 237-246.

Variances for initial and final weight and for gains are segregated into their components. The variations due to errors in weighing feed lot steers constitute about 0.4% of the variance between animals for 3-day initial weights and about 1.18% for single-day initial weights. Corresponding values for 3-day final and single-day final are 0.33% and 0.97% respectively. The reduction of the experimental error due to the 2 extra weighings is thus 0.79% for initial weights and 0.65% for final weights. The variations due to errors in weighing constitute 1.16% of the variance between animal gains based upon 3-day weights, and 3.41% for single-day weights. The reduction in the variance between animals (experimental error) due to the 4 extra weighings is thus 2.27%. The reduction for 2-day weights is 1.7%, and the reduction of the variance of 3-day weights over 2-day weights is 0.58%. Likewise, only relatively small reductions in the size of the variance between animals resulting from extra weighings were found for both the winter and summer pasture-grazed steers. The precisions gained by weighing more than once at the beginning and end of a test can be relatively costly. In these experiments the same degree of precision as obtained from 3-day weights would have been expected from single-day weights if the number of animals had been increased only slightly. Thus, data from 11 animals with single-day weights would be expected to be slightly more efficient than those from 10 animals with 3-day weights.--R. E. Patterson.

Phillips, R. W., and Brier, G. W.
1940. estimating weights of lambs at a constant age. U.S. Dept. Agr. Cir. 541, 16 pp., illus.

Through a statistical treatment of the actual growth data for lambs of different breeds, the following formula was derived for estimating the weight of lambs at a constant age: $Z\left(\frac{20-A}{X-A}\right) = Y$, in which Y is the estimated weight, Z the actual weight at the actual age X, 20 a constant age (any other constant age can replace 20), and A the age intercept, i.e. the point at which a line representing the slope of the growth-curve in the vicinity of the constant age intercepts the age axis. Two short-cut methods for estimating weights are outlined: in one, the weight of the lamb is simply multiplied by a predetermined factor; in the second the estimated weight is read directly from a chart designed for that purpose.--Expt. Sta. Rec.

Phillips, Ralph W., and Stoehr, John A.
1945. the accuracy of measurements and weights of sheep. Jour. Anim. Sci. 4(3): 311-316, illus.

Results of 6 studies to determine the accuracy of measurements of sheep are presented. Accuracy of weight was also determined in 5 of these studies. Measurements that appear to be most accurate, and at the same time measure characteristics which experimenters may desire to study, include height at withers, length from mid-front of scapula to pin bones, width at shoulders, depths of chest and middle, circumferences of chest and middle, and circumference of foreshank. Measurements obtained from animals in fleece or from enlarged photographs are generally less accurate than direct measurements on sheared animals. The difficulties of interpreting measurements in terms of carcass or other values are pointed out. This study indicates that many measurements can be taken with reasonable accuracy, and some external measurements will undoubtedly be of use in interpreting the results of many experiments. Little has been done to determine the relation between external measures and scores and the characteristics of the carcass or other measures of the real productive ability of the animal. There is need for much study on this phase of measuring performance. To avoid unnecessary work the measurements taken in any study should be limited to those for which definite use is planned in the specific experiment under consideration, until more is known of the relation between external measures and merit of the animal. --R. W. Phillips.

Ruby, Ellis S., Blunn, C. T., Brouse, E. M., and Baker, Marvel L.
1948. relation of initial weights and subsequent gains of weaning calves. Jour. Anim. Sci. 7(3): 279-282.

Data gathered from calf wintering and grazing trials conducted at the Valentine substation from 1927 to 1946 were analyzed. The period consisted of two parts, winter and summer. Relations between initial weight, weight at the close of the winter period, final weight, winter gains, and summer gains were determined. The discussion was on an intralot basis because several rations were fed during the winter. Results in general showed a closer relation between contiguous weight and gains than between weight and gains separated by an interval of the feeding period. The correlation between winter gains and summer gains was negative, indicating that high winter gains were followed by lower summer gains. In general, animals with the heavier initial weights for either the winter or summer period were heavier at the end of the summer period but their superiority in weight had decreased. Animals which made the greater winter gains tended to make the lower summer gains.

FECAL COUNT

Arnold, J. F., and Reynolds, H. G.
1943. droppings of arizona and antelope jack rabbits and the "pellet census." Jour. Wildlife Mangt. 7(3): 322-327, illus.

Using hand-reared, captive jack rabbits, the authors studied the effect of age, sex, size, species, and type of food on the number and weight of pellets voided. Pellet number remained constant, on the average, irrespective of age, sex, size, or species of rabbit. The age and weight of mature animals did not affect the weight of pellets voided by either species. Changes in character of the forage consumed caused marked variation in pellet weights but did not cause significant variations in pellet numbers. A highly significant, linear relationship was found between pellet weight and weight of food consumed. When suitable sampling methods are employed, pellet weights can be used to determine the amount of range forage removed by jack rabbits. Pellet counts may be used to estimate fluctuations in rabbit numbers since they are less affected by the character of the forage eaten than are pellet weights. --Biol. Abs.

Bennett, Logan J., English, P. F., and McCain, Randal.
1940. a study of deer populations by use of pellet-group counts. Jour. Wildlife Mangt. 4(4): 398-403.

Year-round pellet-group counts of white-tailed deer (Odocoileus v. virginianus and O. v. borealis) in several forest types in Pennsylvania indicated that such counts can be used for determining approximate deer populations, deer movements, and the utilization of forest types by deer. The counts were made monthly during the spring and summer on 1/10-acre quadrats and on strips 11 ft. wide and varying from 700 to 2,640 ft. in length.--L. J. Bennett.

Riney, Thane.
1957. the use of faeces counts in studies of several free-ranging mammals in new zealand. New Zeal. Jour. Sci. and Technol. Ser. B. 38(6): 507-532, illus.

Records taken in a zoo of the daily number of defecations for four mammal species showed: red deer, 10-0; fallow deer, 11-3; goat, 10-5; and brush tailed possum, 6-3. The size and shape of faecal pellets for each species are described, and it is shown that their location affects the rate of drying of the pellets, and consequently the accuracy with which the age of pellets can be subjectively assessed. In the field, the technique described is designed to provide an index to the density of animals to show numerical trends in populations. It involves careful examination of mil-acre plots situated at regular intervals along lines in selected parts of the study environment. Results are expressed as number of defecations per hundred plots. Basic assumptions in the use of pellet techniques both for censusing and as a density index are

discussed. Field trials designed to explore limitations of the technique show: (1) that one observer can duplicate the results of another (to within five defecations per hundred stations); (2) that differences in the number of faeces along a line are commonly associated with differences of animal habitat, and with changes in season. Numbers of defecations along a line can be expressed either as number of plots containing one or more defecations or as total number of defecations. Faeces count techniques can be used to give: (1) a description of the habitat preferred by each of several mammalian species, (2) a record of differences in seasonal use of habitats based on changes in seasonal distribution of the faeces, (3) an objective measure of substantial population fluctuations following shooting operations. An analysis of variation of faeces counts for all sample lines run in a drainage gives a measurement of the evenness of the distribution of a species in the drainage. Increases in coefficients of variation following hunting are interpreted as evidence of discontinuity of hunting effort; the persistence of this discontinuity, as indirect evidence of localized movement. The use of short-term 10-station lines is described as a means of quickly obtaining objective information during rapid field surveys. Several practical applications to management are discussed, and the need for general agreement on some uniform way of expressing records of faecal droppings is emphasized.--Auth. sum.

Robinette, W. Leslie, Ferguson, Robert B., and Gashwiler, Jay S.
1958. problems involved in the use of deer pellet group counts. North Amer. Wildlife Conf. Trans. 23: 411-425, illus.

Our studies have shown that increased sampling of deer pellet groups is necessary with a decrease in size of area of unit being sampled, with a decrease in pellet group density and in decreased uniformity of pellet group distribution. Circular plots were found to be more efficient sampling units than strip plots. The 100-square-foot circular plot was found to be more efficient than the 0.01-acre circular plot where pellet group densities of 300 or more/acre prevailed. We advise against the use of plots smaller than 100 square feet because of the possible influence of bias in plot location. Our surveys indicated the optimum spacing (considering time and accuracy) of transects to be about 20 chains with 100-square-foot circular plots spaced from about 4 to 12 chains apart along the transects. Optimum transect and plot spacing, however, will vary considerably from one survey to another. Much less sampling is required to establish deer herd trends than for a census, a factor which may prove of value to administrators faced with limited budgets.--Biol. Abs.

Rogers, Glenn, Julander, Odell, and Robinette, W. Leslie.
1958. pellet-group counts for deer census and range-use index. Jour. Wildlife Mangt. 22(2): 193-199.

Daily defecation rate for Rocky Mountain mule deer (<u>Odocoileus h. hemionus</u>) was studied in typical winter range pastures at Little Hills Experiment Station, Colorado from 1951 to 1955. Pastures were stocked lightly to moderately. Average overwinter daily defecation rate was

about 15 groups. A lower figure is suggested for depleted ranges. Counts on plots previously cleared of pellets agreed closely with those on uncleared plots. Factors affecting recorded defecation rates and the intensity of sampling needed for use in deer census work are discussed.--Odell Julander.

Taylor, R. H., and Williams, R. M.
1956. the use of pellet counts for estimating the density of populations of the wild rabbit, oryctolagus cuniculus (l.). New Zeal. Jour. Sci. and Technol. Ser. B. 38(3): 236-256, illus.

A technique is described for estimating rabbit populations from the density of faecal pellets on the ground. The method involves two steps: (1) estimating the number of pellets present, and (2) relating the number of pellets to the number of rabbits by measuring the rate at which pellets decay, and the number of pellets produced daily by individual rabbits. The theory and field procedure of sampling methods devised to measure the density of pellets and their decay rate are given. Attempts made to determine the mean number of pellets produced per rabbit per day resulted in a figure of 820 being accepted for the wild rabbit in New Zealand. The results from several trials carried out during the development of the method are discussed, and an example is given of its practical applications.--Auth. sum.

Beruldsen, E. T., and Morgan, A.
1937. irrigated pastures - rotational grazing. yield sampling and botanical analysis. Victoria Dept. Agr. Jour. 35: 94-103.

Ten acres were divided into two pastures of 2.5 acres and 10 of 0.5 acre for the study of rotational systems of grazing. The 2.5 acre pastures were grazed alternately every 10 days and the 0.5 acre pastures changed daily. Periodic botanical surveys and yield samplings were carried on to determine amount and quality eaten as well as relative palatability of component species. Principle of stocking was to put on enough stock to graze out a pasture in the specified time. Yield sampling method was by cutting 25 to 28 sq. link samples located at random within each 0.5 acre to the ground level before grazing and 35 samples after grazing. A hand operated shearing machine was used. Clippings were composited, oven dried, cleaned and analyzed. A difficulty of this method was in clipping to ground level, particularly in wet weather before and after grazing. Total amount eaten by 89-lb. ewes was 7.8 lbs. of green herbage (80 percent moisture) per day. This is low compared to Cockayme's 24 lbs. and Stapledon and Jone's 11.3 lbs. for 130 to 137-lb. sheep. In the trial, consumption varied from 3.5 to 22 lbs. Considering high nutrient value of feed eaten, 78 lbs. for a growing sheep seems adequate using Woodman and Evans starch equivalent of 1.08 lbs. per day for a 114-lb. sheep. Consumption is highest in spring and summer and is markedly affected by cold rainy weather. At all times the herbage eaten was of very high value, always higher in protein and lower in fiber than that left. When small amounts were eaten, the small leafy portion was taken; when larger amounts taken, stemmy material was also eaten. Yield sampling is so drastic in its action that the same unit cannot be clipped twice in succession; on small areas severe detriment may occur where periodic clippings are frequent.

Brandt, P. M., and Ewalt, H. P.
1939. pasture yields as measured by clip plots and by grazing dairy cows. (Abstract) Jour. Dairy Sci. 22: 451-452.

Yield from an area of 8.72 acres of mixed grass and <u>Trifolium repens</u> pasture grazed for the fifth consecutive season has been measured. The grazing method yielded about 5 percent total digestible nutrients less than the clip plot method which is considered a satisfactory means of determining pasture yield.

Castle, M. E.
1953. grassland production and its measurement using the dairy cow. Brit. Grassland Soc. Jour. 8(3): 195-211.

An original evaluation technique, designed for measuring the output of pasture in terms of the weight of milk produced per acre, has been described. The results obtained by the use of this technique in three consecutive years have been given. In 1949, 1950, and 1951 output was 4,460, 5,530, and 4,660 lbs. of milk per acre respectively. Of the two swards recorded, the ryegrass yielded 18.7 percent more milk than the cocksfoot sward. The milk-producing value of the sward declined with advancing season and averaged 25.1 lb. per day over the three years. The production of dry matter from the ryegrass and cocksfoot swards averaged 6,630 and 6,840 lb. per acre respectively over the three year period. The average annual application of artificial fertilizer was equivalent to 6.4 cwt. per acre. The apparent mean daily consumption of dry matter was 2.9 lb. per live cwt. in 1949 and 1950 and 2.5 lb. in 1951. The total output of the ley determined from the nutrient requirements of the stock averaged 25.1 cwt. of utilized starch equivalent per acre per year. Output calculated from the herbage data was 9 to 23 percent higher than that calculated from the animal data. The evaluation technique and some practical implications arising from the trial have been discussed.

Cory, V. L.
1930. methods of determining forage preference of stock. Ecology 9: 760-763.

As opportunity affords, range livestock show preferences in feeding upon the various forage plants. Noting and recording the time devoted to feeding upon the various species of forage plants gives a rather accurate measure of the forage preferences of stock for that particular range and for similar ranges under similar conditions. Any such study should be conducted at regular intervals over a period of many consecutive months where grazing is continuous, or for a number of consecutive grazing seasons where grazing is seasonal. The changes of vegetation and the trends of these changes may be measured by surveys of grazed areas at intervals of years, or by comparison of grazed areas with inclosed, ungrazed areas of sufficient size to include fair samples of the native vegetation. The survey of vegetation changes is complementary to the measurement of forage preferences of stock through accurate observation, and, together, these two methods furnish a basis for the study of range management problems.

Cox, C. P., Foot, A. S., Hosking, Z. D., and others.
1956. the direct evaluation of pasture in terms of the milk production of individually grazed cows. Brit. Grassland Soc. Jour. 11(2): 107-118.

The possibilities of pasture evaluation in terms of milk production have been examined, experimentally, using individually grazed cows on a ryegrass-clover ley. A significant linear relationship between mean milk-yields and estimated dry-matter intakes over a three-week period was obtained. Under the conditions of this experiment it was

found that the relationship between milk yields and estimated fresh-herbage intakes was also linear, the correlation coefficient being as high as that between milk yields and dry-matter intakes. An intake-output equation was calculated in the form:

$$y = 0.2900x_1 + 0.0117x_2 + 2.1139x_3$$

where y = dry-matter intake, x_1 = fat-corrected milk yield, x_3 = live-weight gain, all in lb. per day, and x_2 = live weight in lb. The precision of estimates of dry-matter intake using sample herbage cuts and dry-matter determinations has been examined. The numbers of cows required in comparative experiments with two treatments to give a 95 percent chance of detecting given differences between mean yields of milk and fat-corrected milk have been estimated.

Davies, R. O., Milton, W. E. J., and Lloyd, J. R.
1950. pasture productivity in mid-wales. I. experimental methods of measurement. Empire Jour. Expt. Agr. 18(71): 203-217, illus.

Different methods of measuring pasture productivity on permanent and reseeded pasture over a period of three years are discussed. Methods are: (1) three-week period growth measurement of caged grass after trimming, (2) difference between yields of untrimmed, caged areas and adjacent grazed areas after three weeks caging, and (3) weights of sheep and lambs at beginning and end of the above periods.

Davis, R. R., and Bell, D. S.
1957. relationships of lamb response and measurements from caged samples in a comparison of birdsfoot trefoil-bluegrass and ladino clover-bluegrass for pasture. Agron. Abs. 49: 70.

_______, and _______.
1958. a comparison of birdsfoot trefoil-bluegrass and ladino clover-bluegrass for pasture: 2. yield of herbage and relationships to lamb response. Agron. Jour. 50(9): 520-524.

During 1953-1955, Lotus corniculatus/Poa pratensis pasture yielded more forage than Trifolium repens var./P. pratensis pasture when their dry-matter yield was estimated by using grazing cages. A greater herbage yield was obtained under continuous grazing by lambs during the first year, and under rotational grazing during subsequent years. Forage samples from pasture including T. repens contained more N during 1953, only. After 1953, rotationally-grazed pasture contained more N than that continuously grazed. There was a close relationship between dry-matter yield and animal-carrying capacity and between the percentage of N in the forage and daily gain of lambs, but not between yield and animal gain/acre.--Herb. Abs.

Deeny, M. C.

1958. an investigation into utilized grassland production on ten farms in north county dublin. Brit. Grassland Soc. Jour. 13(4): 247-254.

Utilized grass production on ten small farms in North County Dublin has been estimated using (A) the method adopted by the British Grassland Society Sub-Committee on the assessment and recording of the utilized output of grassland, and (B) a live-weight increase method using Woodman's figures. At the beginning of the grazing season all the grazing animals on each farm were weighed. At the same time the records for method A were begun. Altogether 169 animals and 12 sheep were weighed during March-April. Animals sold during the period of investigation were weighed, where possible. The results obtained using the two methods have been compared. Average percentage difference on ten observations was 11.3 percent with a variation of ± 3.7 percent. On farms 1-5, where only mature stock were kept, the percentage difference was 9.9 percent ± 2.2 percent. On farms 6-10, where animals of all categories were grazed, the percentage difference averaged 12.8 percent ± 2.2 percent. In all cases the live-weight-increase method gave the higher estimated yield. The techniques used in the estimation of utilized grassland production are discussed. Total output varied between 26.5 cwt. and 9.0 cwt. of utilized starch equiválent per acre. The significance of the findings is discussed and the value of the methods used is considered.

Hein, Mason A., and Henson, Paul R.

1942. comparison of the effect of clipping and grazing treatments on the botanical composition of permanent pasture mixtures. Amer. Soc. Agron. Jour. 34(6): 566-573.

Studies were made at Beltsville, Maryland. Grasses common to the north humid region and white clover in 8 mixtures were used in a study comparing frequent clipping with a lawn mower to grazing with sheep. The clipped plots were mowed to a height of 1.25 inches whenever the growth reached a height of 4 to 6 inches. The grazed areas were pastured when the grass reached a similar height, using sufficient animals to graze the mixtures uniformly in three days or less. The results were measured by making five random counts on each plot with the inclined point quadrat. Readings were made in the spring and fall during the course of the experiment and results reported as to the relative frequency of each species. Under grazing the relative frequency of Kentucky bluegrass, redtop and white clover was greater while orchard grass remained unchanged by clipping or grazing. The sheep, however, refused to graze the latter grass as closely as other species. In general the clipping treatments were more severe than grazing, as evidenced by the lower total relative frequency of the grasses under clipping.--Biol. Abs.

Ivins, J. D., Dilnot, Jean, and Davison, J.
1958. the interpretation of data of grassland evaluation in relation to the varying potential outputs of grassland and livestock. Brit. Grassland Soc. Jour. 13(1): 23-28.

When livestock are used to measure the output of pasture, the potential output of the animal is on occasions lower than that of the grassland so that this may determine the yields of animal products which are obtained, regardless of pasture type and treatment. The implications of this are discussed in relation to the interpretation of data of grassland evaluation, and also in relation to maximum utilization of grass.--Auth. sum.

Jones, I. R., Ewalt, H. P., and Haag. J. R.
1937. a comparison of pasture returns from actual grazing and clip plot methods. Jour. Dairy Sci. 20: 420-421.

The study was made on a 15-acre irrigated Trifolium repens and grass pasture, which was divided into three 5-acre pastures for rotational grazing, during the pasture season April 30 to October 1. The data presented show that production of total digestible nutrients estimated by the clip plot method is considerably higher than the actual returns from pasturing with cattle, and that cattle appear to utilize only about 75 percent of luxurious pasture herbage as measured by the clip plot method.

Kidder, Ralph W.
1946. a proposed method of measuring pasture yields with grazing cattle. Jour. Anim. Sci. 5(2): 187-193.

A proposed adaptation of the indirect method of measuring pasture yields with grazing cattle is described, based on the Morrison feeding standard of 7.93 lb. of total digestible nutrients per day for maintenance of a 100-lb. cow and that the maintenance requirement for animals of other weights is proportional to the 0.73 power of the live weight. The average nutrient requirement for daily maintenance of animals of any weight can be calculated by the formula $\frac{W^{0.73}}{19.53} =$ T.D.N. An analysis of three Florida steer-feeding experiments by this method shows that 330 steers consumed an average of 3.15 lb. of total digestible nutrients for each lb. gain in live weight. Considering the number of variables involved, the difference is not great between this and 3.53, the accepted factor for gain in weight. Using this method, the amount of grass consumed by grazing steers has been closely estimated and has been found to be within the range of annual yields of grass previously reported from this station.

Large, R. V., and Spedding, C. R. W.

1957. the growth of lambs at pasture. 1. a comparison of growth on long and short ryegrass swards. Brit. Grassland Soc. Jour. 12(4): 235-240, illus.

For these experiments, gang mowing proved to be better than varying the stocking rate as a method of maintaining short swards (height index of 1 to 2 in.); the latter method gave differential effects in the lamb weights arising from parasitism. The long-grass swards (height index of 2 to 7 in.) were the very lightly grazed control plots. It was not until mid-June that there was any difference in height index or quality of the treated or control plots. The difference in height of sward was not accompanied by marked differences in growth of lambs. Experience showed that, for this type of experiment, the taller swards should be grazed by means of frequently moved folds and that the introduction of the stock should be delayed until differences in sward height have been established. [For height index see Spedding and Large, 1957, under POINT].--Herb. Abs.

Lassiter, C. A., and others.

1956. the effect of continuous vs. alternate grazing and the effect of barn manure on production and digestibility of bluegrass pasture as measured by grazing dairy heifers. Ky. Agr. Expt. Sta. Bul. 642, 15 pp.

The pastures studied consisted mainly of Kentucky bluegrass (Poa pratensis) and white clover (Trifolium repens). The first series of trials reported were carried out during 1936-1948 to compare continuous and rotational grazing systems. Two rotationally grazed pastures, each of 2.9 acres, were used, with 2-week grazing periods followed by 2-week resting intervals. Mean total digestible nutrient yields on pastures continuously and rotationally grazed were 2290 and 2284 lb. per acre, respectively. There was a close positive relationship between pasture productivity and total seasonal rainfall and an inverse relationship between productivity and mean temperature during the period 1 May to 30 September (72° F. during these trials). In a second series of manurial trials, continuously-grazed pastures were top-dressed with 0, 3, 6, or 9 tons of dung per acre. Mean annual forage yields, as calculated from the weight gains of grazing dairy heifers, were 2161, 2443, 2585, and 2650 lb. TDN, respectively. The average crude-protein contents of the forage and the apparent digestibility of the forage, as determined by the faecal chromogen and forage methods, were not materially affected by the dung treatments used. The average dry-matter content of the forage was slightly reduced by dung applications. The discrepancies between the results of TDN calculations based on cage clippings and on grazing heifers are discussed.--Herb. Abs.

Linehan, P. A., and Lowe, J.

1946. the output of pasture and its measurement. Brit. Grassland Soc. Jour. 1(1): 7-35.

Grass output on 66.3 acres of young ley was measured by (a) periodic clippings according to the movable cage method, and (b) periodic weighings of 100 bullocks from March 23, 1945, to June 28, 1945, and 34 bullocks from August 13, 1945, to September 5, 1945. The two methods employed were compared by computing the nutrients supplied by the grass as measured by clippings with the nutrients computed to have been necessary for the maintenance and live weight increase of the stock. Total output by the movable cage method over the experimental period differed from that based on animal weighings by only 6.8 percent. The coefficient of correlation for the yields obtained for the eight grazing periods is 0.885. The coefficients of variability averaged 26 percent for clips inside the caged areas and 58 percent for cuttings on the outfield grazed areas. It is suggested that a major source of error in the movable cage method is the taking of cuttings too infrequently during periods of rapid herbage growth. The output per acre up to the 5th of September amounted to 3.85 cwts. of live weight increase in 132 animal grazing days. For the entire season up to the 31st of October the grass output amounted to 24.6 cwts. of starch equivalent per acre, of which about 70 percent was obtained by mid-June. Grazing was very thorough, about 80 percent of the grass available in each grazing period being consumed by stock, and only some 1.73 cwts. of dry matter per acre being left uneaten at the end of each grazing period. The severe early season defoliation is felt to be partially responsible for the extreme falling-off in growth in midsummer, and for casualties among the plants which were noted at this time. Probably higher total productivity for the season would have been secured if the herbage was further forward in growth at the beginning of the grazing periods and not so severely defoliated at the ends of the grazing periods. The experimental results are in substantial agreement with those obtained on different type pastures and with other kinds of livestock by many cited workers. The investigation is being continued.

Linehan, P. A., Lowe, J., and Stewart, R. H.
1947. the output of pasture and its measurement. Part II. Brit. Grassland Soc. Jour. 2(3): 145-168.

Grass output on 102.4 acres of young ley was measured in the 1946 season by (a) periodic clippings according to Movable Cage Methods I and II, and (b) periodic weighings of 120 bullocks from April 16 to April 24, 119 bullocks from April 25 to May 29, 132 bullocks from May 30 to July 20, 88 bullocks from July 21 to August 26 and 68 bullocks from August 27 to September 18. The three methods employed were compared by computing the nutrients supplied by the grass as measured by clippings with the nutrients computed to have been necessary for the maintenance and live-weight increase of the stock. Total output by the two Movable Cage Methods employed differed from that based on animal weighings by 18.2 percent in the case of Cage Method II and by 49.0 percent in the case of Cage Method I. The coefficient of correlation between individual period yield figures as measured by Cage Method II amounts to 0.74, while the coefficient

of correlation between period output figures by animal with that from Cage Method I also amounts to 0.74. The evidence suggests that Cage Method I has a very considerable error during periods when growth is rapid and where the length of the grazing period is prolonged. The formula for Cage Method II seeks to make allowance for the difference in yield of the grass permitted unimpeded growth in cages during the grazing period and that subject to defoliation outfield. Collecting together the data for the experimental periods in 1945 and 1946 the relative yield figures taking output by Animal Method as 100, are output by Cage Method II, 95 and by Cage Method I, 128. The apparent consumption figures of grass per animal per day as measured by Cage Method II agree better with grass consumption data reported by other workers than do those computed by Cage Method I. The coefficients of variability averaged 25 percent for clips inside the caged areas, 30 percent for the pre-grazing cuts, and omitting one anomalous reading, 48 percent for cuttings on the outfield grazed areas. These figures have to be regarded as minimum estimates of error since the sampling sites were not chosen entirely at random. Output per acre up to September 18th amounted to 3.20 cwt. of live-weight increase in 164 stock grazing days. For the entire season up to 1st of November the total grass output by Cage Method II amounted to 28.2 cwt. of starch equivalent per acre, of which only 41 percent was obtained by mid-June. By deliberate intent grazing was not as thorough as in 1945, about 4-1/2 cwt. of dry matter per acre being left uneaten at the end of each grazing period. The data support the view that higher grassland productivity under the conditions obtaining in this experiment can be secured by long rest periods and lenient defoliation. On the whole the results obtained up to date are in agreement with the idea that the Movable Cage Method provides a good measure of pasture output. The investigation is being continued.

Linehan, P. A., Lowe, J., and Stewart, R. H.
1952. the output of pasture and its measurement. Part III. Brit. Grassland Soc. Jour. 7(3): 73-98.

Measurement of grass output on 102.4 acres (1947) and 92.7 acres (1948) of young leys was continued in 1947 and 1948 by: (a) periodic clippings according to clip Methods 1, 2, and 3, and (b) periodic weighings of store bullocks which varied in number from 80 to 132 during the grazing seasons. The four methods employed are compared by computing the quantities of nutrients supplied by grass as measured by clippings with those calculated to have been necessary for maintenance and liveweight increase of the stock. Total output by clip Method 2 in 1947 was identical with that based on animal weighings, while yields by clip Methods 1 and 3 differed from that based on animal weighings by <u>plus</u> 29 percent and <u>minus</u> 37 percent respectively. Output by the same clip methods in 1948 differed from that based on animal weighing by <u>plus</u> 7 percent in the case of clip Method 2, <u>plus</u> 39 percent for clip Method 1 and <u>minus</u> 30 percent in the case of clip Method 3. Summarizing for the 4 years of the trial, output by Method 2 was 1 percent higher, by Method 1, 32 percent higher and by Method

3, 31 percent lower than yields based on animal weighings. The coefficients of correlation between total annual yields by clip Methods 2, 1, and 3, and those derived from animal weighings (each based on four readings) were 0.95, 0.93, and 0.92 respectively. Correlation for the 40 individual grazing periods was not so satisfactory, the coefficient being 0.62 in the case of Method 2. The variance attaching to grass consumption yields derived from clippings from each sample site by clip Method 2 amounted to some 51 percent in 1947 and 45 percent in 1948, the average approximating to 50 percent. As measured by clip Method 2, 25.5 lb. dry matter in 1947, and 30.2 lb. dry matter in 1948, and over all four years, 27.6 lb. dry matter were consumed per animal per day. These figures appear to be reasonable for the class of stock under trial and are in line with results reported by other workers, and hence are construed as evidence of the validity of clip Method 2. On the whole, it is concluded that the grass clip Method 2 employed in this experiment provides a good measure of pasture output under conditions parallel to those obtaining in this trial. Output per acre by clip Method 2 amounted to 22 cwt. starch equivalent in 1947 and 31 cwt. starch equivalent in 1948 (the latter figure includes 11 cwt. starch equivalent harvested as silage). These figures compare with 26 cwt. starch equivalent and 19 cwt. starch equivalent per acre in 1946 and 1945 respectively. Measured liveweight increase over the experimental periods and estimates derived from grass yields during the remainder of the season indicate an annual liveweight gain of 4.4, 3.8, 4.0, and 4.9 cwt. per acre during the seasons 1945, 1946, 1947, and 1948 respectively. The average liveweight gain per animal per day over the four seasons of the trial was 2.7 lb. but higher figures were obtained at the beginning of each grazing season, while a marked reduction was nearly always evident in the month of July. Under the system of grassland management employed it was possible, on the average, to supply a full ration of grass for about 0.6 mature bullocks per acre during the months of April, July, August, and early September but a stocking rate of about double this figure was possible during the months of May and June. Although not reflected in reduced output over the four seasons, there was a progressive decline in the contribution of the principal sown grasses to the sward. At the end of the trial, however, perennial ryegrass was still the dominant species present. Earliest spring growth was obtained on swards containing Italian ryegrass which were fertilized early in the season. Data over the four seasons support the view that higher grassland productivity can be secured by long rest periods and lenient defoliation. Dealing with the relationship of grass consumed to liveweight gain secured, altogether 464 2-1/2 year-old bullocks (46,748 cattle grazing days) made a measured liveweight gain of some 54 tons, consuming, as estimated by clip Method 2, 2,987 tons green grass, equivalent to 560 tons dry matter and 321 tons starch equivalent. Thus, as measured, on the average, 1 lb. of liveweight gain was produced by 6 lb. of starch equivalent, 10.5 lb. of dry matter or almost 56 lb. of green grass.--Auth. sum.

Morrison, H. B., and Ely, Fordyce

1946. clipping vs. grazing by dairy heifers as means of estimating yield of bluegrass pastures. Jour. Dairy Sci. 29(7): 393-405.

Yield of a Kentucky bluegrass pasture in terms of TDN (Total Digestible Nutrients) per acre was calculated from clipping with a lawn mower and from grazing with dairy heifers during 5 seasons, 1940-1944, inclusive; the grazing season ranged from 168 to 210 days in length. Yield calculated from grazing was higher than that calculated from clipping in each of the 5 seasons. The calculations from clipping were 50.1, 48.1, 56.4, 91.1, and 82.1 percent of those from grazing in 1940, 1941, 1942, 1943, and 1944, respectively. The average calculated yield from clipping was 68.5 percent of that from grazing. The maximum, minimum and average yields of TDN calculated from clipping were 2218, 889, and 1578 pounds per acre respectively, and from grazing 2615, 1849, and 2305 lb. The average daily amount of TDN furnished by the pasture for an entire season ranged from 4.88 to 12.36 lb. per acre as calculated from clipping, and from 10.16 to 13.59 lb. as calculated from grazing. The trend of the curves representing calculated yield obtained by clipping and grazing with heifers were, in general, quite similar, although a pronounced change in yield usually occurred in the grazing curve 2-3 weeks later than in the clipping curve. The data obtained in this experiment indicate that the clipping method of measurement may be used in a preliminary way to evaluate variables in experimental management of Kentucky bluegrass pastures.

Neenan, M., Conway, A., and Murphy, W. E.

1959. the output of irish pastures. an application of the b.g.s. method for determining the yield of pastures on individual farms. Brit. Grassland Soc. Jour. 14(2): 78-87.

During the years 1956 and 1957, an attempt was made to assess the output of Irish Pastures using methods proposed by a Sub-Committee of the British Grassland Society. It was found that the best results were obtained when output was determined on a single field, rather than on the whole farm basis. The yields showed highly significant correlations with both botanical composition and nutrient status of the pastures. The results were in agreement with the findings of others working on similar grasslands. It is suggested that the method might find a useful place in a program either of advisory work or surveys concerned with grassland improvement.

Petersen, R. G., Weswig, P. H., and Cowan, J. R.

1958. measuring palatability differences in tall fescue by grazing sheep. Agron. Jour. 50(3): 117-119.

This study was designed to find a method of objectively rating a large number of tall fescue genotypes for their relative palatability

to grazing animals. Twenty genotypes were grazed for 2 days by 12 sheep on each of 5 separate occasions. In three of the trials, samples of forage were taken from each plot before and after grazing to estimate the amount of forage consumed during the trial. On each of the five occasions the grazing behavior of the sheep was observed for periods of varying length. The clipping method generally gave unreliable consumption estimates primarily because of the sampling errors involved. By using an observational technique consistent differences in the apparent palatability of the 20 selections were measured. The technique consisted of allowing 12 sheep to graze for a period of 2 days and recording, at 5-minute intervals from 7:00 to 10:00 a. m., the number of sheep grazing on each plot. Relative palatability was then expressed as the total number of times the plot was grazed during the observational period. The largest palatability differences among the 20 genotypes were observed during the flush growth period in the spring. The clipping and observational methods were compared. The observational method appears advantageous for assessing palatability in the small plot stage.--From auth. sum.

Raymond, W. F.
1957. the measurement of pasture output. Nutr. Soc. Proc. [London] 16(1): 20-25, illus.

In a review of systems of pasture evaluation, the importance of seasonal distribution of herbage yield, the necessity for data on herbage consumption in relation to animal production and the indirect methods in use for the estimation of pasture output are considered. --Herb. Abs.

Rhoad, A. O., and Carr. R. B.
1945. measuring productive capacity of pastures through maintenance studies with mature steers. U.S. Dept. Agr. Tech. Bul. 890, 20 pp.

By controlling at weekly intervals (1) the area over which a fixed number of mature steers could graze, (2) the number of steers on a fixed area of pasture, and (3) the daily consumption of green forage of steers in dry lot, and by obtaining quantitative and qualitative analyses of clippings from pastures, it was determined, over 3 grazing seasons, that mature steers consumed for maintenance 49.7 lb. of green forage furnishing 13.02 lb. of dry matter, 1.17 lb. of digestible protein, and 8.77 lb. of all total digestible nutrients daily per 1,000 lb. of liveweight. The average weight of the steers throughout the 3 grazing seasons differed from the 3-day initial weights by 3.1, 1.6, and 0.3 percent under methods (1), (2), and (3) above. The production of forage on 3 pastures computed from pasture clippings was 26, 44.7, and 68.3 percent greater than the production computed from observed consumption in dry lot and carrying capacity of experimental pastures.

Robinson, R. R., Pierre, W. H., and Ackerman, R. A.
1937. a comparison of grazing and clipping for determining the response of permanent pastures to fertilization. Amer. Soc. Agron. Jour. 29: 349-359.

The response of pastures to fertilizer and lime treatments as measured by grazing has been compared with the response as measured (1) by clipping permanent plots and (2) clipping by the "difference-method," i.e., obtaining the difference between the yields of temporarily enclosed areas and the corresponding grazed areas. Although the yields obtained by clipping permanent plots have shown a progressive decrease in relation to the yields obtained by grazing, there has been a high correlation in any one year between the yields from clipping and the yields from grazing. A method is suggested whereby the clipped yields can be expressed in terms of grazing units.

Salcedo, Luis Fernandez.
1932. on the evaluation of pastures. Agricultura [Madrid] 4: 76-79.

A simple method of calculating the yield of pastures is described. A certain sum, called the "coefficient," is calculated as the value of the pasture grazed in a day by an animal, varying according to its species, age, etc. For example, the coefficient for a bull of four years or over is taken as 0.55 pesetas, for a milk cow, 0.40 pesetas, for a heifer, 0.35 pesetas, for a yearling calf, 0.25 pesetas, and so forth. A record is kept of the number and class of cattle grazed, of the dates of entry into the pasture and of leaving it. The number of grazing days is then multiplied by the number of cattle of each class individually, and the result multiplied by the coefficient for the class in question, this giving in pesetas the partial yield of the pastures. The results thus obtained for each class are added together, giving the total yield of the pastures. --Herb. Abs.

Schultz, E. F., Langford, W. R., Evans, E. M., and others.
1959. relationship of beef gains to forage yields. Agron. Jour. 51(4): 207-211.

A quadratic relationship was demonstrated between forage yield and live-weight gain where steers and heifers were grazed on pastures of Cynodon dactylon, Paspalum notatum, and P. dilatatum/Festuca pratensis/Trifolium repens mixtures.--Herb. Abs.

Sears, P. D.
1943. pasture-plot measurement techniques. New Zeal. Jour. Sci. and Technol. 25(5): 177-190.

A system is described whereby a return of droppings is made in proportion to actual plot yields. This method gives better data, more correct as to total yields as well as botanical composition. This is in contrast with the method of mowing and grazing without return of droppings, which gave too little grass growth, and the system of free return of stock droppings, which unduly favors plots with good ryegrass strains, even when the clover content may be poor.

Stapledon, R. G., and Jones, Martin G.
1927. the sheep as a grazing animal and as an instrument for estimating the productivity of pastures. Welsh Plant Breeding Sta. Aberystwyth, Bul., Ser. H 5: 42-54.

During seasons in 1925 and 1926, sheep weighing from 122 to 137 pounds consumed 9.8, 16.7, and 24.2 pounds of green herbage and 2.6, 2.6, and 3.4 pounds of herbage dry weight. Calculated back from the dry weight figures, the sheep consumed 11.3, 11.3, and 14.8 pounds of green herbage per day, using the same moisture content of the herbage.

Weir, W. C., and Torell, D. T.
1959. selective grazing by sheep as shown by a comparison of the chemical composition of range and pasture forage obtained by hand clipping and that collected by esophageal-fistulated sheep. Jour. Anim. Sci. 18(2): 641-649.

Hand-clipped forage from range land and from irrigated and non-irrigated pasture not previously grazed, contained an average of 4.1 percent less protein and 3.5 percent more crude fibre than forage consumed by sheep grazing the same areas. On similar pastures previously grazed by sheep, hand-clipped forage contained 3 percent less protein and 0.9 percent more crude fibre than forage consumed by sheep.

Willoughby, W. M.
1958. a relationship between pasture availability and animal production. Austral. Soc. Anim. Prod. Proc. 2: 42-45.

In an experiment with Merino sheep grazing Phalaris/subterranean clover pasture, the maximum rate of live-weight gain was attained only when at least 1400 lb. dry weight of green material was available per acre. The results are discussed in relation to pasture utilization.--Herb. Abs.

III. STATISTICAL THEORY AND METHOD

TABLE OF CONTENTS

PART III

A. FREQUENCY DISTRIBUTIONS

1. TRANSFORMATIONS OF VARIATES

Anscombe, F. J.
1948. the transformation of poisson, binomial and negative-binomial data. Biometrika 35(3/4): 246-254.

Transformations having the effect of approximately normalizing Poisson, binomial and negative-binomial variables are given to within a constant appearing in each transformation. Optimum values of the constants are defined as those which make the variance of the transformed variable most nearly constant, with obvious application in the technique of analysis of variance. Asymptotic formulae are given for the first four moments and for the efficiency in estimation of the original parameters for transformed variables of each of the three types. A table gives numerical results for representative values of the parameters of each type.

Bartlett, M. S.
1947. the use of transformation. Biometrics Bul. 3(1): 39-52.

The transformations useful on raw statistical data are summarized, with particular reference to the analysis of variance. The various reasons for transformation are outlined, and the type of data for which each transformation is appropriate is discussed. Considerations are given to the square root, logarithmic, inverse sine, and probit transformations, as well as to that of expected normal scores. Illustrations are used.

Bliss, C. I.
1938. the transformation of percentages for use in the analysis of variance. Ohio Jour. Sci. 38(1): 9-12.

Of value in experimental data measuring percent germination, percent mortality, etc.

Bross, Irwin D. J.
1958. how to use ridit analysis. Biometrics 14(1): 18-38.

In many scientific studies in the biological and behavioral sciences the response variables fall in the "borderland" between dichotomous classifications and refined measurement systems. Sometimes the response variable is a subjective scale (e.g. "minor," "moderate," "severe") and other times the response variable is numerical but the measurement system is heavily dependent upon details of protocol. These "borderland" response variables may not be adequately analyzed by either of the two traditional families of statistical techniques

(i.e. the chi-square and t-test families). In this situation ridit analysis serves as a "missing link" between the two traditional families. In ridit analysis a specified class of individuals is chosen as the "identified distribution" and the other series are considered relative to this identified distribution. The ridit for a given category is simply the proportion of individuals in the lesser categories plus one half of the proportion of individuals in the category itself. Once the transformation has been made the data may be analyzed along the lines of the usual t-test families. The use of the ridit transformation is illustrated on data from a study of automotive crash injuries.--Auth. Abs.

Clark, Andrew, and Leonard, Warren H.
1939. the analysis of variance with special reference to data expressed as percentages. Amer. Soc. Agron. Jour. 31(1): 55-66, illus.

It is necessary to apply a transformation, $p = \sin^2\theta$, to certain types of discrete and percentage data where it is proposed to combine the data for the determination of a generalized standard error. Bunt data originally published by S. C. Salmon are employed to illustrate the transformation which indicates that the majority of the data are sufficiently homogeneous as to admit combined treatment. A sampling technic of using the plant rather than the head is recommended. Homogeneity tests are necessary if a generalized standard error is to be a valid measure of variability in the aggregate data.

Cochran, W. G.
1938. some difficulties in the statistical analysis of replicated experiments. Empire Jour. Expt. Agr. 6: 157-175.

1. Discussion of a clear case where variances of different treatments are widely different and should not be pooled. He partitions the d.f. by individual treatment comparisons.
2. Discussion of several types of special treatment: (a) where widely variable data can be discarded (as check plots, which are of no direct value as to effects of fertilizers), (b) by transformations.
3. Discussion of square-root transformation for small numbers and those in Poisson distribution.
4. Discussion of inverse-sine transformation for data in binomial distribution.
5. Discussion of logarithmic transformation where the variance is proportional to the square of the mean (or the S.E. of mean).
6. Discussion of use of transformations in factorial experiments.

Ghurye, S. G.
1949. transformations of a binomial variate for the analysis of variance. Indian Soc. Agr. Statis. Jour. 2(1): 94-109.

Transformations of the binomial variate which reduce considerably the variation in the variate even for such small values as n=10 have been

discussed in this paper. The square root transformation seems to be satisfactory for estimating the variability. The inverse sine transformation does not appear to be accurate enough. The solution of the problem has been attempted by the actual evaluation of the variance for different values of p in different inverse sine transformations for n=10, 15 and 20. There is an appreciable difference as regards the constancy of variances even for n=20 between the different transformation tests. For n=10, the inverse transformation in which $\frac{0.2}{n}$ is added when the variate x=0, and is subtracted for all other values of the variate, appears to be the best transformation. For n=15, the inverse transformations are made by increasing or by decreasing the variate by $\frac{0.2}{n}$ when the variate x=0 and 1, respectively.

Haldane, J. B. S.
1937. the approximate normalization of a class of frequency distributions. Biometrika 29(3/4): 392-404.

By a change of the variable it is possible to make a number of probability distributions approximate very closely to normality. The transformations may be used where the integral of the distribution is not tabulated.--Biol. Abs.

Irwin, J. O.
1943. a table of the variance of $\sqrt{x}$ when x has a poisson distribution. Roy. Statis. Soc. Jour. 106(2): 143-144.

Let $\mu = \sqrt{x}$. The author shows that the variance of μ is $\frac{1}{4}$ for large samples. A table is given containing the values of the variance of $\sqrt{x}$ for various values of μ, the mean. This variance is almost equal to $\frac{1}{4}$ for small values of the mean. This table gives values of the variance of the square root of x for values of μ equal to 0.0, (0.1), 15, 20, 50, 100 and ∞.--Biol. Abs.

Rao, C. Radhakrishna.
1958. some statistical methods for the comparison of growth curves. Biometrics 14(1): 1-17.

Tests for comparison of average growth curves for groups of individuals treated differently have been developed. Some of these tests are exact and useful when the sample size is small. An attempt is made to transform the time axis in such a way that average rate of growth is uniform, to the extent possible, with respect to the new time metameter for each group. The differences between groups in the rates of growth so defined are subject to a test. The adequacy of a common transformation for all the groups is also examined. Tests appropriate for large samples have also been derived. Other topics discussed are the factor analytic models for individual growth curves and discrimination of growth curves when observations are taken continuously.--Auth. Abs.

Upholt, William M.

1942. the use of the square root transformation and analysis of variance with contagious distributions. Jour. Econ. Ent. 35(4): 536-543.

The possibility of bias and the power of the analysis of variance and related tests were investigated in a hypothetical experiment for the case in which the data follow a contagious distribution and are transformed by adding ½ and extracting the square root before applying the analysis. The transformation introduces a bias but in reasonable cases this bias is not sufficient to invalidate the analysis. The type of distribution and possible effects of treatments may result in such a great generalized error term that the analysis has very little power to detect rather large differences in means that may occur. At least until more powerful tests are available for such cases, analysis of variance of the transformed data may be a satisfactory guide for the experimenter if not too much reliance is placed on the results. --Biol. Abs.

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1944. the power of the analysis of variance with the poisson distribution. Jour. Econ. Ent. 37(5): 717.

A previous paper described a hypothetical experiment that showed the square root transformation and analysis of variance to have a low power, when applied to contagious distributions. The present paper employs a similar experiment to show the power of this statistical procedure to be much greater when applied to Poisson distributions, the case for which it was designed.

Wadley, F. M.

1943. statistical treatment of percentage counts. Science 98: 536-538.

Standard methods discussed have some limitations in application to enumeration data of the percentage count type. However, where percentages are based on adequate and similar numbers, where they are between 10 and 90 percent, and where individuals succeeding and failing each total 20 or more in a treatment, these methods may be used. With more extreme percentages, a transformation may be of help, and larger total numbers may be needed.

2. CONTAGIOUS DISTRIBUTIONS

Archibald, E. E. A.

1948. plant populations. I. a new application of neyman's contagious distribution. Ann. Bot. [London] (n.s.) 12(47): [221]-235, illus.

The discussion is based on data from about 10,700 quadrats from 5 maritime and 2 grassland communities. Neyman's contagious series brings into prominence a fundamental issue, viz, that plant populations are more likely to show contagion or grouping of individuals in a heterogeneous manner rather than a distribution at random, the hypothesis of contagion being that when one individual of a species is present other individuals of the same species are also likely to occur. In adapting Neyman's series for the analysis of plant populations, two parameters are defined: m_1 is proportional to the mean number of groups per unit area of the field and m_2 is proportional to the mean number of individuals per group. The first term of the series is given by $P(x=0) = e^{-m_1(1-e^{-m_2})}$ and subsequent terms by $P(x=k+1)=$

$$\frac{m_1 m_2 e^{-m_2}}{k+1} \sum_{t=0}^{t=k} \frac{m_2^t}{t!} \ P(x=k-t).$$

In cases where a Poisson series failed to fit because there were too many empty quadrats, Neyman's series gave a good fit; it also clearly portrayed the bimodal nature of the distribution. The relative variance is used as a quick and reliable test for randomness. From the 56 species examined it appeared that it is unusual for "frequent" or "abundant" species to be distributed at random.--From auth. sum.

______ 1950. plant populations. II. the estimation of the number of individuals per unit area of species in heterogeneous plant populations. Ann. Bot. [London] (n.s.) 14 (53): [7]-21, illus.

Data for the number of individuals per unit area for 27 species from the observation of 9,340 quadrats is discussed. It is shown that Thomas's Double Poisson series will give a good estimate of the density of individuals in heterogeneous populations in which the variance is significantly greater than the mean. The estimate is given by the two parameters of the series which can be obtained by observation from the number of quadrats with no individuals and the number of quadrats with only one individual where $P\{0\}=e^{-m}$ and $P\{1\}=e^{-(m+\lambda)}$, m is the estimated mean number of clusters per quadrat and λ is the estimated number of units per cluster additional to the first unit. The estimated mean number of individuals per quadrat is equal to $m(1+\lambda)$. Tables for the estimated parameters and the estimated mean density together with their standard errors are given in the Appendix.--Auth. sum.

Barnes, H., and Stanbury, F. A.
1951. a statistical study of plant distribution during the colonization and early development of vegetation on china clay residues. Jour. Ecol. [London] 39(1): 171-181.

A brief review of the recent literature on the distribution of individuals of a given species suggests that data collected under relatively simple habitat conditions would be of interest. Distributions of individual plants colonizing on china clay residues were plotted. Results are given for a number of plants, and the agreement with Poisson, Neyman and Thomas series examined. Some plants are randomly distributed, others show aggregation. Neyman's and Thomas' series show close agreement since they are based on the same premises. Since the parameters of the latter are more readily interpreted in terms of plant distribution, it would seem the more useful series. The agreement between actual plant clusters, estimated in an arbitrary manner, and those determined from the Thomas parameters is satisfactory for the particular quadrat sizes used. In all cases the quadrat size was adequate to contain a complete cluster. The development of vegetation takes place by spread of "islands" of rush and grass. At this stage the distribution becomes highly contagious, the "islands" forming a series of separate but similar communities.

Beall, Geoffrey, and Rescia, Richard R.
1953. a generalization of neyman's contagious distributions. Biometrics 9(3): 354-386.

Contagious distributions have been found to apply to situations where populations initially exist in randomly scattered clumps and where subsequent outward movements of individuals within clumps are not independent. They have been applied widely to distributions of insects or microorganisms in their natural environments. Neyman originally proposed three types of contagious distributions which did not fit all experimental data. These authors generalized Neyman's distributions and in some cases found better fits to data previously poorly fitted by Neyman's distributions. The generalized distribution is derived and applied to many different sets of experimental data. Comparisons with Neyman's distributions are made on the basis of chi-square goodness of fit tests. A particular case is worked out in detail to illustrate the nature of the computations.

Cole, Lamont C.
1946. a theory for analyzing contagiously distributed populations. Ecology 27(4): 329-341.

Under natural conditions, living organisms are usually contagiously distributed in space, i.e., contrasted to random distribution, too many infertile samples and too many large groups of organisms are encountered. Contagiousness is attributable to any or all of the following factors: inappropriate sample size, sample heterogeneity, common origin of the individuals, and active aggregation. The

hypothesis is advanced that many contagious distributions may be interpreted as composed of various-sized groups of organisms with these groups distributed as units in a Poisson distribution. The mean number per sample of groups containing x organisms is designated as m_x and the mean number of groups per sample as m_g. For the total frequency distribution then, $m_g = \Sigma m_x$, $m = \Sigma x m_x$, and $\sigma^2 = \Sigma x^2 m_x$. Tentative computational methods are developed for determining the m_x values and several empirical distributions are fitted by this means, thus indicating the structure of a population which, under the postulated random process, would yield the observed distributions. This theory of contagious distributions, if tenable, opens many possibilities for population analysis.

David, F. N., and Moore, P. G.
1954. notes on contagious distributions in plant populations. Ann. Bot. [London] 18(69): 47-53.

Past experience has shown that the Poisson series is often inadequate as a model for describing plant populations. Various alternative two-parameter models have been suggested in place of the Poisson series, but they all depend on assumptions which may or may not hold. In this paper a different approach is put forward in that attention is concentrated on the mean number of plants per quadrat and an index of "clumping" or "contagiousness." Examples are given as to the use of these concepts to test for differences between the distribution of a plant in two localities or between two plants in the same locality.

Erickson, Ralph O., and Stehn, John R.
1945. a technique for analysis of population density data. Amer. Midland Nat. 33(3): 781-787, illus.

The distribution of Clematis fremontii var. riehlii on glades in the Ozarks can be regarded as consisting of two component distributions: an "economic distribution" for favorable portions of the glade; and an "adventitious distribution" for unfavorable portions. A method is demonstrated for fitting two Poisson curves to the field data, which permits calculation of means, etc. The method is applicable to distribution data of certain other plants.

Fracker, S. B., and Brischle, H. A.
1944. measuring the local distribution of ribes. Ecology 25(3): 283-303.

Observations on Ribes in five locations in Idaho, Washington, and California where these plants are being eradicated on a white pine blister rust control project indicated that they were distributed locally as if what Neyman has called a "contagious" distribution were superimposed on a random "Poisson" distribution. The authors term this a "mixed" distribution. In determining which quadrats were

occupied by Ribes, an 8 percent systematic sample gave about as accurate information concerning 5-acre blocks as a 4 percent sample did concerning 10-acre blocks. Divergence from the random type of distribution could be measured satisfactorily either by the method of relative variance or by determining proposed D or d factors giving the relation between the total number of Ribes actually present on the block and the number that would be expected in a random distribution judging from the percent of quadrats occupied. The relative variance had the disadvantage of increasing with the unit size of sample, while the D or d factors remained more nearly constant on a given area regardless of sample size.--Biol. Abs.

Gurland, John.
1958. a generalized class of contagious distributions. Biometrics 14(2): 229-249.

This paper develops by considerations of probability generating functions some generalized families of contagious distributions on the basis of a biological model similar to that of J. Neyman, Ann. Math. Statis. 10: 35-57 (1939). One of these generalized families contains as a particular case the family of contagious distributions developed by G. Beall and R. R. Rescia, Biometrics 9: 354-386 (1953). Some examples are given to illustrate how such a generalized family may be fitted to actual data. It is further shown that the limiting distribution of the family considered by Beall and Rescia is a Polya-Aeppli distribution and consequently a simpler formula is available for computing the probabilities. Other limiting distributions of the generalized family which contains that of Beall and Rescia are also obtained. --Auth. Abs.

Skellam, J. G.
1955. quadrat sampling from the mathematical standpoint. Linn. Soc. London, Proc. 165(2): 95-102.

Thomas, Marjorie.
1949. a generalization of poisson's binomial limit for use in ecology. Biometrika 36(1/2): 18-25.

The Poisson situation is generalized by considering a number of primary points distributed over an area and a random number of secondary points associated with each primary point. The area is divided into squares and the probabilities that a square contains 0, 1, 2, ... points are calculated, assuming that the numbers of primary points per square and of secondary points per primary point are independently Poisson distributed. Estimates are obtained for the two parameters by the method of moments and by maximum likelihood. The latter estimates depend only upon the relative numbers of squares containing none or one point. It is shown that the maximum likelihood estimates are not much worse than the moment solutions when there are many squares containing no points or one point.

Thomson, George William.
1952. measures of plant aggregation based on contagious distribution. Mich. Univ. Lab. Vert. Biol. Contrib. 53, 16 pp.

The contagious distributions of Neyman and Thomas, fitted to quadrat frequency data for Solidago rigida, Liatris aspera, and Lespedeza capitata from an old-field community, gave respective fits of excellent, fair, and very poor. The size of the contagious distribution "clusters" of the mathematical model, one to two plants per cluster, had little relation to the obvious major clumping evident to the eye but is more likely related to local clumping effects. A comparison of the observed major clumping with that shown by various measures of dispersion indicated that Lespedeza was most clumped, Solidago least clumped, and Liatris intermediate, but none of these measures indicates the actual size of the clump involved. Size of clump appears to be a new problem demanding further research. An appendix gives a method for the calculation of the individual terms of the contagious series by means of direct calculation of polynomials instead of by the use of summations.

3. OTHER FREQUENCY DISTRIBUTIONS

Birnbaum, Allan.
1954. statistical methods for poisson processes and exponential populations. Amer. Statis. Assoc. Jour. 49(266): 254-266.

The Poisson process and exponential distribution are described and examples of their occurrence in practice are given. Methods are presented for constructing interval estimates of the parameters of the distributions, for making one-sided tests of hypothesis, and for computing confidence intervals for the ratio and the difference of such parameters. A method is also given for comparing three or more Poisson processes.

Bond, T. E. T.
1947. some ceylon examples of the logarithmic series and the index of diversity of plant and animal populations. Ceylon Jour. Sci. Sect. A., Bot. 12(4): 195-202, illus.

The author applies a modification of Willis' "hollow curve" to the Ceylon flora and fauna. The "index of diversity," as controlling the relationships between the number of species in a population and its size, is illustrated by a consideration of the weed flora on a manurial experiment with tea on St. Coombs estate. An apparent discrepancy between the observed and calculated densities of individual plants per unit area is attributed to a peculiarity in botanical composition of the flora as affected by the system of weeding.

Fisher, R. A.
1941. the negative binomial distribution. Ann. Eugenics [Cambridge] 11(2): 182-187.

The cases of the positive and negative binomial distributions, in spite of their algebraic similarity, are very different in their applications and in the statistical problems to which they give rise. With the negative binomial we ordinarily require to estimate the exponent in addition to the mean of the distribution. This can be done from the first two moments, but the process has been recognized as inefficient, and in the present note the theoretical efficiency is calculated so as to make it easy to judge in practical cases whether a more exact fitting by maximal likelihood is required.--R. A. Fisher.

Haldane, J. B. S.
1941. the fitting of binomial distributions. Ann. Eugenics [Cambridge] 11(2): 179-181.

A binomial law can readily be fitted to observed data by the method of maximum likelihood.

Hartley, H. O.
1958. maximum likelihood estimation from incomplete data. Biometrics 14(2): 174-194.

This paper is concerned with the fitting of frequency distributions to counts which are "incomplete." The most important cases of incompleteness covered are: (1) "Missing Frequencies" (Truncation). These arise for instance when the "zero-class count" cannot be observed. An example of this kind is dealt with in detail and is concerned with a chromosome breakage study (Sampford, 1955, Biometrika 42: 58) in which susceptible cells showing no breakage are not distinguishable from cells not susceptible to breaks. (2) Grouped or Pooled Frequencies (Censoring). These arise for example when the number of counts exceeding a tolerance value have all been pooled in one group. The fitting of frequency distributions to such data by the method of maximum likelihood is considerably simplified by a new iterative procedure akin to the missing plot technique in analysis of variance: Trial values are estimated for the missing frequencies and these estimates are iteratively improved by their maximum likelihood estimates until, at convergence, the solution agrees with the (computationally more complex) solution of the maximum likelihood equations. New methods for estimating the variances of maximum likelihood estimates are also developed and illustrated with numerical examples.--Biol. Abs.

Ker, John W.
1954. distribution series arising in quadrat sampling of reproduction. Jour. Forestry 52(11): 838-841, illus.

Moore, P. G.
1954. a note on truncated poisson distributions. Biometrics 10(3): 402-406.

The author presents a quick method for estimating the parameter in a Poisson distribution under all types of sampling truncation likely to occur in practice. He points out that the estimate will have a larger standard error than the corresponding maximum likelihood estimate.--Biol. Abs.

Numata, M., and Suzuki, K.
1958. experimental studies on early stages of secondary succession. III. Jap. Jour. Ecol. 8(2): 68-75. [In Japanese. English summary.]

Experiments for analyzing the developmental process of plant communities on 1-meter permanent quadrats from 1954 to 1957 are reported. The experimental treatments of the quadrats at the beginning are by exchanging the soil (to exchange the surface soil for the subsoil) and by burning the soil (to burn the surface soil 5 cm. deep). Burned-soil plot: The floristic composition shows a yearly change of the dominants Setaria-Digitaria-Bromus, which differs from that of early

stages of a normal successional change in this place: Ambrosia-Erigeron (Imperata-Miscanthus). The dominance-rank relations and composition curve show the differentiation of species groups and their development. Exchanged- soil plot: The floristic composition of the first year is similar to that of the second year on the burned-soil plot. The yearly change of dominants is Digitaria-Ambrosia-Artemisia-Vicia. The dominance-rank relation and composition curve seem to show a development of plant population from Williams' L-type to Preston's S-type. Distribution type: As a stochastic process in the distribution of the number of individuals in a quadrat, the Poisson type related only to the quadrat size a and the geometrical progression type related to a and the number of individuals appeared in a quadrat n are recognized. Time effect and area effect: The distribution type varies as the size of quadrat, and varies with time as the geometrical progression type-Poisson type-Polya-Eggenberger type-binominal type-normal type.--Biol. Abs.

Ottestad, Per.
1934. a contribution to the study of some statistical problems in plant-sociology. NYT Mag. [Oslo] 74: 51-69.

The following problem is examined: Within a larger area (B), n specimens of a certain species exist. What is the probability (s_x) of recording a certain number (x) of specimens within a test-area (b) selected at random? Assuming that the area B is homogeneous (statistically), theoretical examinations lead to the hypergeometrical frequency function:

$$s_x = f\binom{n}{x} = \frac{\binom{n}{x}\binom{B-n}{b-x}}{\binom{B}{b}} .$$

This theoretical result has been verified by an examination of the quantitative occurrence of Potentilla erecta. The individual number of this species within smaller test-areas showed very good agreement with the hypergeometrical frequency function. Further the paper deals with the problem: Within the area (B), k species exist. What is the probability of recording a certain number (y) of these species within a test-area (b) selected at random? If the species are distributed over the area (B) in accordance with the very same frequency law, the probability of recording any y species within a test-area is given by the binomial frequency function: $s_y = \phi(y) = \binom{k}{y}p^y(1-p)^{k-y}$.

The paper also gives a survey of the statistical methods by means of which it can be determined whether a given statistical series can be represented by the binomial function, Poisson's function and the hypergeometrical function.--Auth. Abs.

Preston, F. W.
1948. the commonness, and rarity, of species. Ecology 29(3): 254-283.

Random samples of ecological or taxonomic assemblages indicate that the universes from which they are drawn have, at least approximately,

the form of an ordinary Gaussian curve drawn upon a logarithmic base (a 'lognormal' curve). The sample has the same general form as the universe, but is decapitated. The exact relationship between sample and universe is explored, and the Raunkiaer Law of Frequency explained, as is Williams' Law of Collection Enrichment. There is a remarkable tendency for the dispersion constant '$\underline{a}$' to be not far from 0.2 in a great variety of biological universes. Various applications of the theory are made to rather inaccessible populations, such as the Nearctic avifauna in its entirety. The findings seem reasonable in all cases.

Quenouille, M. H.
1949. a relation between the logarithmic, poisson and negative binomial series. Biometrics 5(2): 162-164.

Relations between logarithmic, Poisson and negative binomial eries are demonstrated by means of generating functions on the assumption that the number of groups observed on any one occasion is distributed in the Poisson form, so that the probability of observing n groups is $P\ (n\ \text{groups}) = \frac{e^{-m}m^n}{n!}$.

Robinson, P.
1954. the distribution of plant populations. Ann. Bot. [London] 18(69): 35-45, illus.

In studying the distribution of plant species in sample quadrats it may be assumed that the individuals are aggregated into groups showing a Poisson distribution, while the number of individuals in each group follows a logarithmic distribution. The resulting compound distribution of individuals per quadrat is the negative binomial. Evidence is produced to show that the distributions calculated on this basis agree with those actually obtained in the cases examined.

Schrek, Robert, and Lipson, Henry I.
1941. logarithmic frequency distribution. Human Biol. 13(1): 1-22.

The routine methods of representing frequency distributions yield asymmetrical curves. By using the logarithmic instead of the arithmetic values of the data, the asymmetrical curves become symmetrical. The logarithmic curve is described by the frequency constants: geometric mean, geometric standard deviation, logarithmic skewness, and logarithmic kurtosis. The computation of these constants is as easy as the determination of the corresponding arithmetic constants. The logarithmic method of analysis of distributions includes the use of tables, histograms, probability curves, and frequency formulae, all in logarithmic form. The logarithmic frequency curve for many statistical distributions in biology and medicine is more satisfactory than the arithmetic one. The geometric mean is often more significant than the arithmetic. Similarly the geometric standard deviation is more useful than the arithmetic standard deviation and the coefficient of variation. Furthermore, the logarithmic frequency formula is, in these cases, more satisfactory than the Pearsonian.

Singh, B. N., and Chalam, G. V.
1937. a quantitative analysis of the weed flora on arable land. Jour. Ecol. [London] 25(1): 213-221, illus.

A total of 95 sq. m. quadrats arranged in 19 5-sq.-m. plots were examined in a field with a history of uniform crop production. Twelve species were listed and the number of occurrences of each species accounted for in every quadrat. The data were compared with Poisson distribution and the agreement between observed and calculated values tested by x^2. Overdispersion (patchiness) was great for species with high mean frequencies but for those with low mean frequencies the distribution was not distinguishable from random dispersion. This led to the conclusion that the nature of distribution of weed species on arable land is dependent on the mean density of the species and the mode of reproduction. Individuals with high mean density and vegetative methods of propagation are not distributed at random.

_______, and Das, K.
1938. distribution of weed species on arable land. Jour. Ecol. [London] 26(2): 455-466.

In a statistical study of the distribution of individuals of weed species made in small plots of arable land left fallow for a short time, it appears from comparison with the terms of a Poisson series that distribution usually tends to be random (13 out of 21 examples). Determination of the relative variance indicates, however, that all the species except four show a value which is slightly more than unity, indicating a small degree of aggregation. This is corroborated by the determination of the degree of heterogeneity made on the distribution of individuals of one species by employing Ashby's technique of comparing the observed and calculated empty squares in quadrats laid at random. There is good agreement between the results obtained by either relative variance or the empty square technique. The former method is more rapid but the latter more precise.--Biol. Abs.

_______, and _______.
1939. percentage frequency and quadrat size in analytical studies of weed flora. Jour. Ecol. [London] 27(1): 66-77, illus.

While investigating the distribution of the individuals of weed species in small plots of arable land which were left fallow for a short duration, the relationships between the percentage frequency and density and between the quadrat size and mean number of species were studied. The theoretical logarithmic relation between percentage frequency and density holds in the case of the weed species, but is only approximately true since most of the weed species show a small degree of heterogeneity in the distribution of their individuals. When calculated and observed densities are compared by their standard errors as determined by the formula suggested by Bartlett, it is revealed that although the weed species are characterized by a slight degree of heterogeneity, the densities of some species may be determined.

The difference between the observed and calculated densities is insignificant for those species where the agreement with the calculated Poisson series terms is significant. When the relationship between the quadrat size and the average number of species found within the quadrat size is studied, a disagreement between the field and calculated data is revealed which however improves when the less common species are excluded. The disagreement is correlated with the heterogeneity in the distribution of the individuals of the weed species.

Sneyers, R.
1955. sur l'analyse des répartitions statistiques discrétes. [on the analysis of discrete frequency distributions.] Arch. f. Mét. Geophys. u. Bioklimatol., Ser. B. [Austria] 7(1): 117-132.

The analysis of discrete frequency distributions may be reduced to the study of four fundamental variables, related to each other in a recurrent manner. The binomial distribution and derived distributions are examined and examples given.--Auth. sum.

Sprott, D. A.
1958. the method of maximum likelihood applied to the poisson binomial distribution. Biometrics 14(1): 97-106.

The method of maximum likelihood to estimate a and p is applied to the distribution

$$P(k)=e^{-a}\sum_{t=0}^{-0} \frac{a^t}{t!} \binom{nt}{k} p^k q^{nt-k}$$

to give the equations $n\hat{a}\hat{p}=\bar{k}$ and $L(\hat{p})=\Sigma a_k\ F(k)-N=0$, where $F(k)=\dfrac{(k+1)P(k+1)}{n\hat{a}\hat{p}P(k)}$

and $\hat{a}$ and $\hat{p}$ are the estimates of a and p and a_k is the observed frequency of k. If $\hat{p}'$ is an approximate solution, then a closer approximation is $\hat{p}''=\hat{p}'-L(\hat{p}')/L'(\hat{p}')$, where it is shown

$$L'(\hat{p})=\Sigma a_k F(k)\left[\frac{1}{\hat{p}}-\frac{1}{n\hat{p}}-\left(1+\frac{\hat{q}}{n\hat{p}}\right)n\hat{a}\ \Delta F(k)\right].$$

The large sample variances of $\hat{a}$ and $\hat{p}$ are also derived. It is shown that estimation by the method of moments is inefficient unless $p\leq .1$ and that estimation by the method of sample zero frequency remains reasonably efficient for considerably larger values of $p(p \leq .3)$.

Spiller, D.
1948. truncated log-normal and root-normal frequency distributions of insect populations. Nature [London] 162(4118): 530-531, illus.

Because of many zero values there is skew distribution: e.g., number of eggs laid by *Anobium puncatum* females, or number of red scales (*Aonidiella aurantii*) on citrus leaves. Using Gaddum's probit methods,

straight lines result from log n + 1 (to accommodate zero values) plotted against probits for red or black scales; for Anobium data a square root transformation is used. If the counting unit is increased (e.g., 20 leaves for scale) until zero values disappear, normal statistical methods may be used, but for data already published, the above method of comparison by linear regression is preferable.

Upholt, William M.
1944. the power of the analysis of variance with the poisson distribution. Jour. Econ. Ent. 37(5): 717. [See TRANSFORMATIONS OF VARIATES]

Wadley, F. M.
1950. notes on the form of distribution of insect and plant populations. Ent. Soc. Amer. Ann. 43(4): 581-586.

Several theoretical distributions applying to populations of organisms per unit area are described and examples of fitting are shown. The distributions are fitted to a number of cases of field populations of Ribes bushes, wireworms, and Japanese beetle larvae. The negative binomial was more successful than the contagious distribution and the Poisson series.

Williams, C. B.
1944. some applications of the logarithmic series and the index of diversity to ecological problems. Jour. Ecol. [London] 32(1): 1-44, illus.

A logarithmic series, first suggested in this connection by R. A. Fisher, is applied to a number of problems of the division of individuals into species and of species into genera. The series is N_1, $(N_1/2)x$, $(N_1/3)x^2$, $(N_1/4)x^3$,...., where N_1 is the number of groups of one unit and x a constant less than unity. When several samples are taken from a population containing a number of species the ratio N_1/x is constant and is called the index of diversity. It is found to fit extremely well to a large number of frequency series drawn from populations of insects, birds, and plants except for a slight tendency for the calculated N_1 to be below the observed. It also fits well the number of genera with different numbers of species in standard classifications of groups of animals and plants. The concept of the index of diversity is applied to problems of the number of species of plants on different areas and to the comparison of different floras.

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1947. the logarithmic series and its application to biological problems. Jour. Ecol. [London] 34(2): 1-20, illus.

An account is given of the mathematical properties of the logarithmic series, so far as they are of interest to biologists. This frequency series, which may be conveniently written, αx; $\alpha x^2/2$; $\alpha x^3/3$; $\alpha x^4/4$; ..., etc., usually represents the number of groups containing 1, 2, 3, etc., units. Thus in a random sample of insects from a wild population the series fits the number of species, represented by 1, 2, 3, etc., individuals. In the series as written above "α" is a property of the population sampled and is of considerable ecological interest. It has been called the Index of Diversity. "x" on the other hand is a property of the sample and is a constant, < 1, for each sample. Instructions are given for calculating the logarithmic series to fit various types of data, and references are given to a number of published biological applications.

Williams, C. B.
1950. the application of the logarithmic series to the frequency of occurrence of plant species in quadrats. Jour. Ecol. [London] 38(1): 107-138.

Previous work on the frequency distribution of species with different numbers of individuals in mixed animal populations has shown that the distribution conforms fairly closely to a "logarithmic series." This present paper is a study of the application of the same mathematical approach to the frequency distribution of different species of plants in quadrat samples. It is shown that this distribution (whether taken as the number of species found on 1, 2, 3, 4, etc., out of a total number of quadrats; or as species found on 0-20 percent, 20-40 percent, ..., etc., of the quadrats) is dependent on three factors: the number of quadrats, the size of the quadrat, and a measure of the diversity of the association. This measure of diversity is one of the constants, alpha, in the formula for the logarithmic series, or can be measured proportionately by the rate of increase of species as the size or number of quadrats is increased. The size and number of quadrats can be varied at will by the observer; the real ecological factor determining the distribution is therefore the diversity of the population.

B. SAMPLING DISTRIBUTIONS

Anscombe, F. J.
1948. the transformation of poisson, binomial and negative-binomial data. Biometrika 35(3/4): 246-254. [See TRANSFORMATIONS OF VARIATES]

Bartlett, M. S.
1947. the use of transformation. Biometrics Bul. 3(1): 39-52. [See TRANSFORMATIONS OF VARIATES]

Chapman, R. A.
1938. applicability of the z test to a poisson distribution. Biometrika 30(1/2): 188-190, illus.

One hundred samples of 16 values were drawn experimentally from a Poisson distribution with a mean equal to one. Each sample of 16 was divided into four equal subsets. For each sample two estimates of the variance of the population were computed, i.e., variance between means of subsets and variance within subsets. The distribution of the ratio of these two variances, or F, was compared with the theoretical distribution. Agreement between actual and theoretical frequency of F, as measured by X^2, was satisfactory. $P(X^2)$ was about 0.5.

Cochran, W. G.
1940. note on an approximate formula for the significance levels of z. Ann. Math. Statis. 9:93-95.

Deming, W. Edwards, and Birge, Raymond T.
1934. on the statistical theory of errors. Rev. Mod. Phys. 6(3): 119-161; also in Phys. Rev. 46(11): 1027.

A set of n equally reliable observations may be viewed as a sample of n variates drawn from an infinite parent population of observations; hence the interpretation of experimental data obtained in a scientific investigation is a problem in sampling and should be handled as such. The authors discuss some of the recent developments in statistical methods as they affect a single set of observations drawn from a "normal" parent population. These results are put into a form suitable for use in the interpretation of data obtained in the laboratory. The contents of the paper include a discussion of the sampling distributions of the error u in the mean $\bar{x}$ of a set of n observations, their standard deviation s, the "Student" ratio u/s, and the statistical tests that arise from these distributions. Newly designed charts and tables are shown for convenience in making these tests. R. A. Fisher's notion of "fiducial probability" is applied to the distribution of s, and a table for the fiducial 5 percent and 50 percent points in the probable error of the mean is given. The odds are 19 to 1 that the

true probable error in the mean is less than the 5 percent fiducial probable error; for the 50 percent probable error the odds are even. Various methods for estimating the probable error are given. Fisher's method of "maximum likelihood" is discussed and illustrated analytically and graphically. The methods of Bayes and Laplace for the application of "inverse probability" are illustrated with Molina and Wilkinson's curves. It is shown that there is no possible way of expressing mathematically a state of complete ignorance of the prior probabilities. The paper contains illustrative examples, and closes with an introduction to the estimation of the probable error in the mean of a series of observations, when several series of observations of equal precision are at hand.--Biol. Abs.

Jeffreys, Harold.
1941. some applications of the method of minimum X^2. Ann. Eugenics [Cambridge] 11(2): 108-114.

The use of the method of minimum X^2 for estimation is illustrated by numerical applications to three types of problems where the data are frequencies: (1) a Poisson distribution, (2) two negative binomial distributions, (3) a case where no suggested law of chance is available but a certain amount of smoothing is permissible. In the last the method is combined with a method of smoothing that has been found useful in seismological work.

C. ESTIMATION AND HYPOTHESIS TESTING

Birnbaum, Allan.
1954. statistical methods for poisson processes and exponential populations. Amer. Statis. Assoc. Jour. 49(266): 254-266. [See OTHER FREQUENCY DISTRIBUTIONS]

Bliss, C. I.
1958. periodic regression in biology and climatology. Conn. Agr. Expt. Sta. Bul. 615, 55 pp., illus. [See REGRESSION]

Brieger, F. G.
1942. coeficiente de variacão e índice de varianca. (coefficient of variation and index of variance) Bragantia [Brazil] 2(9): 313-331.

The present paper studies the usefulness of two relative measures of variation, the well-known coefficient of variation and a new term proposed in this paper and called the index of variance. These terms are defined by the equations: coefficient of variation:

$$\sigma\% = \frac{\sigma}{\bar{v}} \times 100; \text{ index of variance: } \frac{\sigma}{\sqrt{\bar{v}}}.$$

It is shown that, for theoretical reasons, only the index of variance may be expected to be constant. Six different experimental series actually proved this constancy, showing at the same time the variability of the coefficient of variation which proved to be dependent upon the respective mean. The coefficient of variation becomes approximately constant when the respective means are sufficiently distant from the absolute limit zero or other biological limits. Thus the index of variance may be used to prove the homogeneity of variation in samples with means of different dimensions. Through this it is shown that the index of variance should be constant, it is explained that for biological reasons we may not always find a good fit between the observed and the expected data. While it seems justified in agricultural experimentation to accept proportionality between mean yield and area, no such relation exists for the standard error. It can only be said that, generally, the index of variance for large areas is not equal, but bigger than that for smaller ones. The coefficient of variation cannot be used as a general term for comparing the variation in series of different dimensions where we must apply the index of variance. But it still retains its value as a measure of the efficiency of experiments. --Auth. sum.

Clark, Andrew, and Leonard, Warren H.
1939. the analysis of variance with special reference to data expressed as percentages. Amer. Soc. Agron. Jour. 31(1): 55-66, illus. [See TRANSFORMATIONS OF VARIATES]

Clopper, C. J., and Pearson, E. S.
1934. the use of confidence or fiducial limits illustrated in the case of the binomial. Biometrika 26(3/4): 404-413, illus.

If x individuals in a random sample of n possess a certain character we may determine confidence limits, p_1 and p_2, for the proportion p possessing the character in the sampled population, such that in repeated samples the prediction that $P_1 < P < P_2$ is correct in a specified percentage of the cases. This percentage is called the confidence coefficient. Charts are given to determine confidence limits and to plan the size of sample necessary to provide a desired degree of accuracy in estimation.--Biol. Abs.

Cole, LaMont C.
1945. a simple test of the hypothesis that alternative events are equally probable. Ecology 26(2): 202-205.

Gives table of $P = \dfrac{2\sum_{0}^{E} \dfrac{n!}{E!(n-E)!}}{2^n}$.

This is from expansion of binomial $(p+q)^{35}$ to $(p+q)^2$ where p=q=0.5.

Corsten, L. C. A.
1957. partition of experimental vectors connected with multinomial distributions. Biometrics 13(4): 451-484.

Methodological paper on the investigation of counts in (possibly non-orthogonal) contingency tables in terms of vectors. On the analogy of the analysis of variance, the partition of a 2X2 table in a level, two main effects, and an interaction is introduced. From this partition follows the well-known decomposition of the X^2-criterion in three components which serve to test the mentioned aspects. A similar partition of a 2^3 table in a level, three main effects, three first-order interactions, and a second-order interaction supplies the decomposition of the X^2-criterion into seven components. The hypotheses which can be tested by these components are given in detail; in particular, the hypothesis of independence of the three classifications in the level must be acceptable. The decomposition of m X n X ... tables is introduced as well. Lancaster's suggestion for calculating X^2, in case cells are pooled, is criticized. The usual warning against amalgamating 2^3 tables to 2 X 2 tables is mostly not justified; rather, judgment of the validity of the null hypothesis of independence is necessary. For each of the cases with one, two or three first-order interactions in the level, respectively, new partitions into interactions and a second-order interaction are given. In the case of three first-order interactions, Bartlett's definition of second-order interaction is followed. The four test criteria for second-order interaction in a 2^3 table are asymptotically equal, unless the number of admitted first-order interactions in the level is too small. The application of Bartlett's method on his example is rejected. In connection with an appropriate model another partition and another definition of "no second-order interaction" is proposed.--Biol. Abs.

Hartley, H. O.
1939. testing the homogeneity of a set of variances. Biometrika 31(3/4): 249-255.

If standard errors are obtained from k groups of experimental data and if it is desired to obtain a standard error common to all groups, it is often necessary to apply a test for inhomogeneity between the k individual standard errors. For general use in such (and related cases) a statistical test, called the L_1 test, has been developed and has been modified recently with the help of a new statistic denoted by μ. In this note a new mathematical formula is found from which numerical values of the probability integral of μ can be readily obtained. A scheme to tabulate the 5 percent and 1 percent levels of μ is proposed and the accuracy of the new formula is compared with that of approximate formulae hitherto in use.--H.O. Hartley.

Katz, Leo.
1953. confidence intervals for the number showing a certain characteristic in a population when sampling is without replacement. Amer. Statis. Assoc. Jour. 48(262): 256-261.

The formulas given are good approximations for populations containing between 25 and 500 individuals. Tables already published give confidence intervals for populations outside this size range. Several examples are worked out.

Miles, S. R.
1935. a very rapid and easy method of testing the reliability of an average and a discussion of the normal and binomial methods. Amer. Soc. Agron. Jour. 21-31.

Moore, P. G.
1954. a note on truncated poisson distributions. Biometrics 10(3): 402-406. [See OTHER FREQUENCY DISTRIBUTIONS]

Neyman, J.
1942. basic ideas and some recent results of the theory of testing statistical hypotheses. Roy. Statis. Soc. Jour. 105(4): 292-322.

The author reviews some of the developments connected with testing statistical hypotheses together with several controverses on this phase of statistics. Ideas concerning the following are presented: definition of a statistical hypothesis, two views of probability, meaning of testing hypotheses, definitions of the two kinds of errors arising in making test, the power function, the power function of a most powerful test, regions and similar regions, tests which are unbiased, tests concerning randomization testing by use of X^2, tables of power functions, the power function of X^2, etc. Assumptions

underlying the test are given, together with difficulties arising in applying them. This synopsis of the developments involved in testing statistical hypotheses is well written, contains many recent discoveries, and shows the rapid progress made in statistical analyses. The appendix discusses the work of R. A. Fisher and Jeffrey.--Biol. Abs.

Neyman, J., and Pearson, E. S.
1931. on the problem of k samples. Polon. Acad. des Sci. et Lettres, Cl. de Sci. Math. et Nat. Bul. Internatl. Series A: 460-481.

Przyborowski, J., and Wilenski, H.
1939. homogeneity of results in testing samples from poisson series. with an application to testing clover seed for dodder. Biometrika 31(3/4): 313-323, illus.

The problem considered is that in which x_1 and x_2 are two independent random variables distributed in accordance with the Poisson law, and it is desired to test the hypothesis that the expectations m_1 and m_2 are the same. It is shown how a test may be derived which is independent of the value of the unknown common hypothetical expectation but which, owing to the discontinuous nature of the probability distributions, will only provide an upper limit to the significance level, i.e., to the chance of rejecting the hypothesis tested when it is true. The manner of approach of the significance level to its upper limit has, however, been investigated numerically. A table has been provided, containing critical values k(na) required in carrying the test. The power function of the test has also been determined, and tables and charts given which make it possible to determine the chance of detecting differences in expectations m_1 and m_2 of specified magnitudes. Some uses of the test are discussed.

D. REGRESSION

Awbery, J. H.
1934. the determination of a parabolic formula to represent a series of observations. Phys. Soc. London Proc. 46(4): 574-582.

When the constants a, b, and c in the formula $y=a+bx+cx^2$ are to be determined from simultaneous values of x and y, the best-known methods involve the addition of a number of equations, which are then solved to give the desired constants. A large number of significant figures must be retained in the calculation. If one constant can be determined separately from the other two, the arithmetic can be greatly simplified. It is frequently advantageous to determine first the constant c, since this is the constant needed to correct mean values to instantaneous values. It can be easily found by the method of divided differences which, in contrast to the more familiar methods, reduces the number of significant figures to the minimum permissible. If the observations are very irregular, the method in its crudest form gives a very poor estimate of c, but a modification is described which adds little to the labor, while considerably improving the accuracy. Numerical examples are given, and the results by the new method compared with those obtained by the methods of least squares and zero sum.--Auth. Abs.

Baker, G. A.
1949. an application of linear regression analysis to biometric data. Poultry Sci. 28(2): 293-297.

The problem discussed is that of finding an estimate of the relationship between white and yolk weights of birds' eggs for all species based on partial data for 24 species and more adequate data for 8 species. The general principles considered for determining a "best" fitting line were freehand, least squares, and maximum likelihood. A well-established principle based on assumptions not sufficiently close to reality may give a poor result. If the assumptions are modified towards reality, the results may be vastly improved. Any mathematical model is only approximate, but the principle of least squares based on sufficiently realistic assumptions seems to give acceptable results.

Baten, William Dowell.
1941. how to determine which of two variables is better for predicting a third variable. Amer. Soc. Agron. Jour. 33(8): 695-699.

This article gives the details for applying Hotelling's test for determining which of two variables is better for predicting a third when the variables are linearly related. The test answers such questions as the following: Can a steer's weight be better predicted from his heart girth than from some other body measurement? Can the area of a bean leaflet be better predicted from the length than from the width? Two applications relating to agriculture are presented together with

charts showing the geometric meaning of the test. The object of the article is to bring to the attention of research workers in agriculture this important test which can be applied in many ways.--W. D. Baten.

Bliss, C. I.
1958. periodic regression in biology and climatology. Conn. Agr. Expt. Sta. Bul. 615, 55 pp., illus.

Periodic regression has been applied to cyclic phenonema in which (1) the length of the cycle, such as the year or day, is determined independently of the response, (2) observations are spaced equally through the cycle, and (3) the number of replicates is constant at each interval. When the response (y) is a symmetrical function of time, it may conform to the sine curve, computed with the equation $Y=a_0+a_1u_1+b_1v_1$, where a_0 is the mean response and a_1 and b_1 are regression coefficients for the orthogonal cosine u_1 and sine v_1 respectively, which lead directly to estimates of the amplitude and phase angle of the curve. When the relation is not symmetrical, the sine curve can be extended with similar additional terms for 2, 3, or more cycles in each fundamental period by classical Fourier analysis. For deciding how many terms to retain in a Fourier curve and for determining its error, an analysis of variance is based upon the mathematical model for replicated regressions. The calculations are illustrated numerically with the monthly mean temperatures in New Haven over a 14-year period, the monthly iodine value in butter fat from 5 creameries in Alberta, and the electrical potential of an elm tree in 8 three-day periods. Both the number of terms in a periodic regression and the validity of its analysis depend upon a suitable measure of the response. The transformation to logarithms is applied to the data on two contagious diseases, and to square roots for a Poisson count to data on the hour of birth. An example of seasonal variation in the log-ED50 for a biocide or drug from all or none data involves the probit transformation. Diurnal variation in the log heat-exchange of cows in an experimental barn is corrected for aperiodic differences in humidity by covariance. Confidence limits are described for the parameters of the sine curve when each statistic is treated separately and when they are considered jointly. Finer adjustments in periodic regression are examined with the monthly mean temperatures in New Haven. These include corrections for differences in the length of the month, seasonal changes in the variance through the year, which proved itself to be periodic, tests for the normality of the variation from year to year within months, and the bearing of these finer adjustments upon climatological predictions.--Biol. Abs.

Dent, Beryl M.
1935. on observations of points connected by a linear relation. Phys. Soc. London Proc. 47(1): 92-108, illus.

The problem of drawing the best straight line through a set of observed points is solved by a method shorter than those previously published.

It is essential for the complete solution of the problem to obtain the most probable value of the ratio of the precision constants of the two observed sets of quantities and a new method is given for finding this ratio. Expressions for the errors in the position and inclination of the line are derived and a numerical example is added. --Auth. Abs.

Mandel, John.
1957. fitting a straight line to certain types of cumulative data. Amer. Statis. Assoc. Jour. 52(280): 552-566.

Involves linear data of measurements made at progressive stages of a process where errors are not independent. Ordinary regression methods applied to wildlife data imply independent errors, often an incorrect assumption.--Biol. Abs.

Schultz, Arnold M.
1956. the use of regression in range research. Jour. Range Mangt. 9(1): 41-46.

Spiller, D.
1948. truncated log-normal and root-normal frequency distributions of insect populations. Nature [London] 162(4118): 530-531, illus. [See OTHER FREQUENCY DISTRIBUTIONS]

E. VARIANCE ANALYSIS

Ashton, G. C., Rennie, J. C., and Etter, E.
1958. interpretation of interaction in the analysis of variance of a factorial experiment. Canad. Jour. Anim. Sci. 38(2): 181-186.

Bourne, J. B.
1938. the importance and use of appropriate assumed means in collating field experimental results statistically. Trop. Agr. [Trinidad] 15: 247-258.

Where results from several trials are combined and averages vary greatly, it is more advantageous to use different assumed means for each trial than one assumed mean, because the labor in calculation is less. This involves some arithmetical manipulation which is described in detail.

Brandt, A. E.
1933. the analysis of variance in a 2 X s table with disproportionate frequencies. Amer. Statis. Assoc. Jour. 28: 164-173.

According to Bartlett, Brandt does not appear to realize all the complications that absence of orthogonality entails. Thus he assumes that the sums of squares appropriate for testing different effects must necessarily be additive as in an orthogonal experiment, and this is not true.

Bullen, E. R.
1956. the interpretation of field trial results. Indian Jour. Agron. 1(2): 133-140.

Capó, Bernardo G.
1944. a method of interpreting the results of field trials. Jour. Agr. Univ. Puerto Rico 28(1): 7-21.

The author describes a method of interpreting the results of field trials involving comparatively large plots in places where soil fertility varies widely between spots relatively near to one another. The method is applicable when testing a small number of treatments.

Cochran, W. G.
1938. some difficulties in the statistical analysis of replicated experiments. Empire Jour. Expt. Agr. 6: 157-175. [See TRANSFORMATIONS OF VARIATES]

Cochran, W. G.
1939. the use of the analysis of variance in enumeration by sampling. Amer. Statis. Assoc. Jour. 34: 492-510.

——— 1947. some consequences when the assumptions for the analysis of variance are not satisfied. Biometrics 3(1): 22-38.

Corsten, L. C. A.
1958. general missing plot technique. Wageningen Rijksinst. v. Rassenonderzock van landbgewassen. Meded. 34: 141-151. [In Dutch. English summary.]

Curnow, Robert N.
1959. the analysis of a two phase experiment. Biometrics 15(1): 60-73.

A statistical analysis, proposed by G. A. McIntyre, (Biometrics 11(3): 324-334, 1955), for a rather complicated two phase experiment is criticized and a more efficient analysis proposed. In this new analysis the variation is more completely broken down into its component parts and two sets of estimates of treatment effects obtained. Apart from being correlated with each other, these two sets of estimates are equivalent to the inter- and intra-block estimates of an incomplete block design. McIntyre's analysis uses the unweighted means of the two sets of estimates. The new analysis weights the two sets so as to give estimates with minimum variance. With the particular experimental results discussed by McIntyre the gain in efficiency is small. The difficulties of estimating variance components are discussed.--Auth. Abs.

Duncan, David B.
1957. multiple range tests for correlated and heteroscedastic means. Biometrics 13(2): 164-176.

Complete multiple range tests have previously been developed for uncorrelated and homoscedastic means. A method is presented for extending these tests to cases with correlated and/or heteroscedastic means such as ones with unequal replications and adjusted means from analyses of covariance and incomplete block designs. A short-cut skipping method is also presented for applying multiple range tests to a large number of means. The properties of the proposed tests are discussed briefly and are concluded to be closely approximate to the ones desired.--D. B. Duncan.

Dutton, A. M.
1952. statistical analysis of long-term agricultural experiments. (Abstract.) Iowa State Col. Jour. Sci. 26(2): 198.

Eisenhart, Churchill.
1947. the assumptions underlying the analysis of variance. Biometrics 3(1): 1-21.

Federer, Walter T.
1957. variance and covariance analyses for unbalanced classifications. Biometrics 13(3): 333-362.

Variance and covariance analyses are classified under three categories, viz., Case I, interaction absent; Case II, interaction present and the effects assumed to be fixed effects; and Case III, interaction present and the interaction effects and at least one of the main effects of the factors represented in the interactions assumed to be random effects. The statistical procedures for the three cases are derived for two-way and three-way classifications and are illustrated with numerical examples for the two-way classification with a covariate. The procedures for a q-way classification with b covariates are indicated.--Biol. Abs.

Fisher, R. A.
1941. the interpretation of experimental four-fold tables. Science 94: 210-211.

Garber, R. J., and McIlvaine, T. C.
1935. analysis of variance of corn yields obtained in crop production experiments. Amer. Soc. Agron. Jour. 27: 480-485.

Glenday, A. C.
1955. the mathematical separation of plant and weather effects in field growth studies. Austral. Jour. Agr. Res. 6(6): [813]-822, illus.

The only serious limitations of field growth studies are due to the erratic nature of the curves caused by short-term weather variations and the less apparent deviations caused by secular changes. The method of constant-fitting is applied, via a suitable mathematical model and experimental design, to separate growth and weather effects. A detailed account of the analysis is given, using a trial conducted as a test of the technique as an example, and the future possibilities of the technique in field growth studies are discussed.--Auth. sum.

Goch, D. C.
1958. examination of residuals in the analysis of varients. So. African Jour. Sci. 54(3): 67-69.

Green, J. U.
1949. herbage sampling errors in grazing trials. Brit. Grassland Soc. Jour. 4(1): 11-16.

Harter, H. Leon.
1957. error rates and sample sizes for range tests in multiple comparisons. Biometrics 13(4): 511-536.

The problem of multiple comparisons has recently aroused a great deal of interest among statisticians. The basic F-test in an analysis of variance determines whether there is a significant difference among a group of means, but it cannot tell which means differ significantly from which others. The latter is often what the investigator really wants to know. Various multiple comparisons tests, including the range tests discussed in this paper, have been proposed. A study is made here of the error rates, α and β and their relation to sample size, N, for three fixed range tests and three multiple range tests. --Biol. Abs.

Healy, M. J. R., and Leech, F. B.
1950. statistical analysis of results for successive tests on the same organism. Nature [London] 166(4216): 319.

Authors admit that Williams (Nature [London] 166(4216): 319) was not in error. Emphasize that if differences increase during an experiment, one needs a linear function of the mean and linear components, with coefficients depending on the variances and covariance of these components. Then the linear function can be calculated for each animal, and significance, etc., can be analyzed from these values.

Hoyle, B. J., and Baker, G. A.
1959. the analysis of field trials based on the concept of islands of variation. Agron. Abs. 1959: 82.

Iyer, T. A. Govinda.
1957. quicker methods in the analysis of variance. Madras Agr. Jour. 44(8): 326-336.

An alternate method of analysis of variance is illustrated by four examples. It involves no use of "Sums of Squares" so is less time-consuming with no loss of efficiency. This method uses certain tables from Pearson's Biometrika Tables for Statisticians, 1954, which are given in an appendix.

Kaltofen, H.
1958. über die fehlerschätzung bei feldversuchen einfachster struktur. [the estimation of error in field trials with one replicate.] Ztschr. f. Acker- u. Pflanzenbau (Berlin) 105(2): 145-168. [English summary.]

Kelleher, Therese, Robinson, H. F., and Comstock, R. E.
1958. precision of estimates of variance components. Biometrics 14(1): 69-77.

Through study of fourth-degree parameters, estimates of variance of components of variance for grain yield in five populations of corn were concluded to be unaffected generally by nonnormality of parent distributions, to the level investigated. From analyses of variance of estimates of components of variance, it was concluded that variability of estimates can be calculated on the assumption of common variances in the parent distributions if sampling is within years. When sampling is among years, some attention must be given to the composition of the individual components which are being estimated.--Biol. Abs.

Kristensen, R. K.
1934. feglberegning ved markforsøg. erstatningstal. [calculation of error in field experiments. exchange values.] Tidsskr. for Planteavl (Copenhagen) 40(1): 161-168.

This article deals with further work on a new method to determine the mean error of experimental results which possess irregular, one-sided deviations. This work is based on the fact that successful tests produce smoother curves than less successful ones. When a calculation of the experimental error is based on degree of smoothness of the curves, smoother curves give smaller mean error than irregular curves. When single values on the curve are compared with the mean, differences obtain, and the mean error is calculated according to the formula:

$$M^2 = \frac{(d^2)}{n} \cdot \frac{2}{3}$$

where d is the differences and n the number of these. The "exchange value" is computed in the following way: If 30 kg. N in $(NH_4)_2SO_4$ gave the same response in yield as 24.1 kg. N in $NaNO_3$, the "exchange value" for $(NH_4)_2SO_4$ is obtained from the proportion

$$\frac{E}{100} = \frac{30}{24.1} \text{ or } E = 124.$$

A discussion on use of rectangular plats versus the "checker board system" is also included; differences obtained from use of the two methods are too small to be of practical importance.--Biol. Abs.

Leech, F. B., and Healy, M. J. R.
1959. the analysis of experiments on growth rate. Biometrics 15(1): 98-106.

A method is presented for the analysis of experiments in which successive measurements of the same quantity are made on the same organism at equal intervals of time. The specification and estimation of treatment effects are discussed and demonstrated by a numerical example. When a treatment effect can be specified by a curve of degree p passing

through the origin, curves of degree p are fitted to the observations and two estimates are obtained of each coefficient of the curve specifying the treatment effect. These can be combined by a method giving minimum variance. Thus when the treatment effect is linear in time, straight lines are fitted to the data and two estimates of the linear coefficient specifying the treatment effect are combined with minimum variance to give an improved estimate. Covariance analysis on initial observations is also discussed.--Biol. Abs.

Madow, William G.
1957. some simple methods of computing parameters in the analysis of variance. Biometrics 13(4): 537-540.

Under general conditions, the degrees of freedom of the quadratic forms occurring in the analysis of variance may be computed by taking expected values or by specified substitutions for the variables. Another substitution yields the parameters of Tang's distribution.--Biol. Abs.

Matérn, Bertil.
1957. a routine for computing the degrees of freedom in analysis of variance. Biometrics 13(4): 541-543.

The degrees of freedom can be automatically calculated along with the computation of sums of squares, as illustrated by an analysis of variance of a factorial experiment.--Biol. Abs.

Rajabhooshanam, D. S.
1935. application of modern statistical methods to yield trials. Agr. and Livestock in India 5(2): 145-155.

A brief summarization of the statistical methods used in interpretation of the significance of small differences in yields.--Biol. Abs.

Rojas, B. A.
1958. the analyses of groups of similar experiments. Diss. Abs. 19(3): 415.

Salmon, S. C.
1938. generalized standard errors for evaluating bunt experiments with wheat. Amer. Soc. Agron. Jour. 30(8): 647-663, illus.

Six experiments dealing with the resistance of several varieties of winter and spring wheat to many collections of bunt were examined with reference to the validity of analysis of variance for measuring random variation. Grouping the data without reference to bunt infection such as is usually done in analysis of variance could lead to serious errors in interpretation. A method of treating such

experiments is suggested in which the data are first grouped according to percentage of bunt and standard errors are then calculated for each bunt class. The binomial formula for standard error modified by a constant derived from the experimental data may be used for estimating the standard errors for those classes in which the numbers are very small. Some of the limitations and precautions which should be observed in using these methods are pointed out.--S. C. Salmon.

Snedecor, George W.
1934. biological variation vs. errors in measurement. Science 80 (2072): 246-247.

In studies of experimental technique, analysis of variance may often be used to estimate the parts of the experimental error attributable to (i) errors in the actual process of measuring the individual, and (ii) variation among the individuals measured. Examples of two contrasting situations are given, together with suggestions as to the improvement of the techniques.--G. W. Snedecor.

_______, and Cox, Gertrude M.
1935. disproportionate subclass numbers in tables of multiple classification. Iowa Agr. Expt. Sta. Res. Bul. 180, pp. [235]-272.

A test conducted on actual and theoretical problems involving disproportionate frequencies testing the actual accuracies of the following methods, expected subclass numbers, fitting constants, weighted squares of means, and unweighted means, finds that in reality there is but very little difference in the results by the various methods.

Each method is based on a postulate concerning a population. If it is reasonable to suppose that the sample was derived from a population described by one of these postulates, then the corresponding method of treatment can be used with greater confidence than otherwise. Usual tests of significance are applicable even when disproportionate frequencies are encountered.

Sváb, J.
1957. approximating analysis of variance without squaring, with especial regard to statistical analysis of field-trials in block-design. Növénytermelés 6(1): 77-90. [In Hungarian with English summary.]

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1958. combined analysis of variance of a series of experiments with partitioning the variation effects into single components; interpretation of interaction. Növénytermelés 7(2): 121-142. [In Hungarian with English summary.]

Tedin, Olof, and Gösta, Julén.
1953. ett fall, där variansanalysen lämner felaktig uppfattning om den statistiska säkerhelten hos ett försöksresultat. (a case, where the analysis of variance gives an erroneous estimate of the statistical significance of an observed difference.) Sveriges Utsädesför. Tidsskr. [Sweden] 63(5): 469-474.

The paper reports a case where a statistical treatment of a trial including different N dressings to timothy leys gives very different results if the old classical method directly based on differences is compared with an analysis of variance. Due to differences in variability and a different correlation between different treatments an erroneous conclusion was obtained when the material was treated according to the analysis of variance. The reasons were analyzed and a warning was given that the method is not absolutely infallible.

Wilkinson, G. N.
1958. estimation of missing values for the analysis of incomplete data. Biometrics 14(2): 257-286.

Equations for missing values can be formed simply by equating each unknown (for a missing value) to its estimated expectation derived from the formally complete data in which the unknowns represent the missing values. The matrix of coefficients of the missing value equations has a simple structure; each coefficient corresponds to a pair of missing values (including identical pairs) and its value is determined by the relation between the pair of missing values in the experimental design. Thus, to facilitate the formation of the equations, a table of relations for the experimental design can be set up, with the corresponding values of coefficients. Note that the inverse of the matrix of coefficients is required in computing correct standard errors. The paper gives a derivation of the basic result, and provides tables of coefficients for some of the standard designs. Solution of the equations by matrix inversion, in particular, is discussed in some detail, and also the solution of singular equations. A concise table for determining missing values in randomized blocks is presented. The procedure of forming and solving equations will generally be simpler than the older method (Yates) of applying the formula for a single missing value iteratively.

Williams, E. J.
1950. statistical analysis of results for successive tests on the same organism. Nature [London] 166(4216): 319.

Author agrees with Leech that it is an error to regard successive tests on the same animal as independent. However, a former analysis by Williams had been misunderstood. In groups of cows treated over

four periods, the comparison was not of main treatment effects, but interaction of treatment with periods; and with null hypothesis, mean squares for treatment-period interaction, and cow-period interaction would be similar whether or not observations on the same animal are independent.

Williams, E. J.
1953. a method of analysis for double classifications. Austral. Jour. Appl. Sci. 4: 357-370.

Yates, F.
1933. the analysis of replicated experiments when the field results are incomplete. Empire Jour. Expt. Agr. 1(2): 129-142.

The procedure introduced by Allan and Wishart for supplying a missing value in a table of experimental results, such as the plot yields of a field trial, so that the treatment means form unbiased and efficient estimates of the treatment effects, is here extended to enable any number of missing values to be replaced, it being shown that the method of derivation adopted previously is equivalent to the simpler method of minimizing the error term in the ordinary analysis of variance.--From auth. sum.

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1934. the analysis of multiple classifications with unequal numbers in the different classes. Amer. Statis. Assoc. Jour. 29: 51-66.

Criticizes some of Brandt's results, and gives a corrected analysis of the data used, according to the principles in a previous paper.

______, and Cochran, W. G.
1938. the analysis of groups of experiments. Jour. Agr. Sci. [England] 28: 556-580.

When a set of experiments involving the same or similar treatments is carried out at a number of places, or in a number of years, the results usually require comprehensive examination and summary. In general, each set of results must be considered on its merits, and it is not possible to lay down rules of procedure that will be applicable in all cases, but there are certain preliminary steps in the analysis which can be dealt with in general terms. These are discussed in the present paper and illustrated by actual examples. It is pointed out that the ordinary analysis of variance procedure suitable for dealing with the results of a single experiment may require modification, owing to lack of equality in the errors of the different experiments, and owing to non-homogeneity of the components of the interaction of treatments with places and times.

F. COVARIANCE ANALYSIS

Bartlett, M. S.
1935. an examination of the value of covariance in dairy cow nutrition experiments. Jour. Agr. Sci. [England] 25:238-244.

The results of a winter nutrition experiment on dairy cows were used as a uniformity trial in order to indicate the magnitude of the standard error we may expect if a continuous treatment experiment is designed with a preliminary control period. An initial period of three weeks is suggested, and some discussion given on the design and analysis of this type of experiment.

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1938. the approximate recovery of information from replicated field experiments with large blocks. Jour. Agr. Sci. [England] 28: 418-427.

The method suggested by Papadakis of using covariance with the yields of neighbouring plots to reduce the error of replicated field experiments is illustrated on two large-scale cotton experiments. In a discussion on the validity and value of the method, it is concluded that for such experiments, where the number of plots per block is large, the method should be approximately valid and sometimes useful.

Bose, S. S., and Gupta, S. C. S.
1935. a study in co-variance with fodder crops. 22nd Indian Sci. Cong. Proc. 1935: 347.

Pennisetum purpureum was grown under six manurial dressings in six randomized blocks at Dacca. The harvest was gathered in three instalments in December (1932), May, and September (1934). The sampling errors calculated from the analysis of variance in the three cases were 6.0 percent, 4.8 percent, and 3.8 percent respectively. The first and second cuttings showed a residual correlation +0.63 based on 25 degrees of freedom and this reduced the second year's estimate of error from 6.20 lb. per plot to 4.96 lb. But second and third cuttings showed very small correlation and thus did not produce any appreciable improvement in the estimate of error.--Auth. Abs.

Brady, J.
1935. a biological application of the analysis of co-variance. Roy. Statis. Soc. Jour. Sup. 2: 99-106.

Using data from an experiment on lodging the author extends the application of covariance in adjusting for concurrent measurements to adjusting for two independent variables. Presents formulae for the calculation of separate b coefficients and for residual sum of squares without use of normal equations. These are simply a summation of the

procedure in normal equations. Extends the procedure to application under two criteria of classification using the treatment plus error procedure with each criterion of classification and also with the interaction. Also splits treatment up into components of between regressions and between means.

Cochran, William G.
1957. analysis of covariance: its nature and uses. Biometrics 13(3): 261-281.

Discusses the nature and principal uses of the analysis of covariance, and presents the standard methods and tests of significance.--Biol. Abs.

Coons, Irma.
1957. the analysis of covariance as a missing plot technique. Biometrics 13(3): 387-405.

The covariance analysis provides a general technique for analyzing data from a statistically designed experiment when one or more observations are missing. The technique may be applied to data from an experiment of any statistical design, and furnishes estimates of the missing observations and exact tests of significance with relatively little computational effort. This paper describes the application of the technique when one or several observations are missing. Specific examples given for fractional factorial and split-plot experiments illustrate the computational procedures involved.--Biol. Abs.

Day, B., and Fisher, R. A.
1937. the comparison of variability in populations having unequal means. an example of the analysis of covariance with multiple dependent and independent variates. Ann. of Eugenics [Cambridge] 7(4): 333-348.

By means of analysis of covariance the regression of standard deviation on mean is obtained. It is found that for leaf length of Plantago maritima, a unit increase in the mean carries with it an average increase of .0332 in the standard deviation. Hence, an allowance made by using the coefficient of variation would be about 30 times too large. They then go on to develop complex correlations involving length, breadth, and thickness, to see how the standard deviation (of length, say) is affected by the other mean values. It is found that the simple values, such as that obtained on the other side, may be quite wrong. In any event, the coefficient of variation is not a suitable quantity. Sample: "variability in thickness is favored by a high average thickness, somewhat favored by low average length, and practically uninfluenced by average breadth."

Duncan, David B.
1957. multiple range tests for correlated and heteroscedastic means. Biometrics 13(2): 164-176. [See VARIANCE ANALYSIS]

Federer, Walter T.
1957. variance and covariance analyses for unbalanced classifications. Biometrics 13(3): 333-362. [See VARIANCE ANALYSIS]

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1959. covariance analyses for unbalanced two-way classifications. N.Y. (Cornell) Agr. Expt. Sta. Mem. 360, 60 pp.

Finney, D. J.
1957. stratification, balance and covariance. Biometrics 13(3): 373-386.

Experimenters sometimes impose on the animals allocated to different treatments the condition that treatment means in respect of some preliminary measurement, believed to be correlated with the measurement that is to be used in assessment of results, shall be approximately equal. Such balance may be used in completely randomized or randomized block designs. The expected variance of treatment means for these designs and for the corresponding randomized designs are compared. Three major criticisms of the balanced designs emerge: difficulty of objective allocation, temptation to omit the necessary covariance analysis, and smallness of any gain in precision. The disadvantages seem far to outweigh the advantages, and such designs should not be used unless special circumstances dictate their advisability. The possibility of using Latin square and allied designs as alternatives to the type of balance discussed is briefly mentioned. When there is anything to be gained by balance, these designs avoid the theoretical objections and will usually have almost equal merits.--Biol. Abs.

Garner, F. H., Grantham, J., and Sanders, H. G.
1934. covariance in analysing field experimental data. Jour. Agr. Sci. [England] 24: 250-259.

Suggest that the covariance method is of considerable value in correcting for uncontrolled equalities arising early in the experiment and in analysing the effects of developmental factors on yield. As an example its application to the results of an experiment with beans is described.

Leech, F. B., and Healy, M. J. R.
1959. the analysis of experiments on growth rate. Biometrics 15(1): 98-106. [See VARIANCE ANALYSIS]

Love, H. H.
1936. are uniformity trials useful? Amer. Soc. Agron. Jour. 28(3): 234-245.

The method of covariance analysis as used by Sanders and Fisher was applied to some results of uniformity trials. Results of other investigators are discussed and the method of analysis given in detail. In some instances the standard error was reduced as a result of removing the effects of regression. Use of uniformity trials is of benefit in suggesting plat lay-out, and analysis of data from other uniformity trials is urged to shed further light on the problem. The refinements of method suggested by Fisher, Bartlett, and Wishart are useful in such studies.--Biol. Abs.

Mahoney, Charles H., and Baten, W. D.
1939. the use of the analysis of covariance and its limitation in the adjustment of yields based on stand irregularities. Jour. Agr. Res. 58: 317-329.

Parker, E. R.
1942. adjustment of yields in an experiment with orange trees. Amer. Soc. Hort. Sci. Proc. 41: 23-33.

Application of simple and multiple covariance to the yield data obtained in three periods of four years each in an extensive fertilizer experiment with Washington Navel oranges, laid out on a background of a six year uniformity trial, indicated that this technique has value for the control of experimental error. The reduction of error was greater when covariance on prior yields was applied than when the effects of "yield blocks" based upon the same prior data were eliminated by analysis of variance. However, the area of cross-section of the trunks and the volume of the tree tops at the time the experiment was started had little value when used as independent variables. The use of covariance on yields of check plots and on prior yields resulted in important reductions in error. The yields of the last year of the uniformity trial had more effect than the yields of any other year in that period, and multiple covariance on the yields of two or more prior years gave superior results to simple covariance on sums (or means) of the same prior years. The greatest reduction in experimental error, which was equivalent to increasing the number of replications per treatment from 4 to 7.4, was obtained by multiple covariance on yields of the last year of the uniformity trial and the current yields of the check plots. It is concluded that rather permanent variations which are correlated with the yields during the uniformity trial, and variations of a more temporary nature, which are correlated with the yields of check plots, are responsible for an important part of the variability in the experimental yields of this orchard, and that their effects can be eliminated by application of the covariance technique.--E. R. Parker.

Pechanec, Joseph F.
1941. application of analysis of covariance to range research data. U. S. Forest Serv. Intermtn. Forest and Range Expt. Sta. Tech. Note. 1, 21 pp. [Processed.]

Smith, H. Fairfield.
1957. interpretation of adjusted treatment means and regressions in analysis of covariance. Biometrics 13(3): 282-308.

This paper considers two of the more important problems which arise in applications of covariance analysis: the interpretation of adjusted means, and the comparison of treatment ("external") and error ("internal") regressions.--Biol. Abs.

Vaidyanathan, M.
1934. the method of "covariance" applicable to the utilization of the previous crop records for judging the improved precision of experiments. Indian Jour. Agr. Sci. 4(2): 327-342.

The use of information based on yields of plots from preliminary uniformity trials in suggesting better plot layouts for permanent experiments is discussed. The method of analysis of results from uniformity trials to obtain increased precision of an experiment as used by Fisher, Sanders, and others, is given in detail. Tables are arranged to show the steps in the analysis and the method is applied to data from tea yields. The improvement in precision is nearly 16 times what it would otherwise be by analyzing the experimental data alone.--Biol. Abs.

Wilkinson, G. N.
1957. the analysis of covariance with incomplete data. Biometrics 13(3): 363-372.

If a set of data y, with corresponding concomitant data $x_1, x_2, \ldots, x_p$, is incomplete in relation to a given experimental design, both the data y and the concomitant data $x_1, x_2, \ldots, x_p$ should be completed with estimated missing values, each set of missing values being determined in the usual way. The (p+1) sets of equations will have the same matrix of coefficients, so that inversion of this one matrix is sufficient to determine all sets of missing values. In the analysis of sums of squares and products for the completed data, the residual line is correct, but the treatments line needs adjustment for a correct test of significance. The necessary adjustment formulae are given. The variance of a treatment comparison (unadjusted) is determined in the usual way (adjustment being made for the missing values), and the additional variance for covariant adjustment of the comparison is given by the standard formula for complete data. Detailed numerical illustration is given.--Biol. Abs.

Wishart, John.
1950. field trials II: the analysis of covariance. Imp. Bur. Plant Breeding and Genet. Tech. Commun. 15, 35 pp.

The objective of communication 15 is to consider the question of simultaneous consideration of two or more observational variables from some plot with a view to presenting methods to take account of soil fertility variations more completely than by mere elimination of block, row, or column differences or to further elucidate the nature of the facts sought. Methods for determining the regressions, correlations, variances, and their interrelations are developed. These methods are illustrated by examples. Significance tests for the different constants are presented.

Zelen, Marvin.
1957. the analysis of covariance for incomplete block designs. Biometrics 13(3): 309-332.

The analysis of covariance for the general case of p concomitant variates is outlined with special reference to incomplete block designs. Both the intra- and inter-block analyses are considered. An appropriate analysis of covariance is also given when the adjustment for the treatment response depends on the differential block responses. Examples of application are included.--Biol. Abs.

G. SAMPLING DESIGN

1. RANDOM SAMPLING DESIGN

Barbacki, S., and Fisher, R. A.
1936. a test of the supposed precision of systematic arrangements. Ann. Eugenics [Cambridge] 7: 189-193.

As in the results found by O. Tedin (Jour. Agr. Sci. 21: 191-208), randomized arrangements give more precise results and smaller errors than systematic arrangements. Systematic arrangements consistently underestimate error and fail to furnish a valid test of significance.

Bourdeau, Philippe F.
1953. a test of random versus systematic ecological sampling. Ecology 34(3): 499-512.

Data from a full tally of an oak-hickory forest stand of the North Carolina Piedmont were used to compare unrestricted and stratified random sampling with systematic sampling on the basis of their respective statistical variances. Over a range of sampling intensities from 2.8 to 33.3 percent of the total area it was found that random sampling, especially when stratified, is only slightly less accurate than systematic sampling, yet it permits a sound estimate of the error, which cannot be done with systematic sampling. Therefore it is suggested that random sampling should be used whenever reliable quantitative data are needed on stand composition.--P. F. Bourdeau.

Cochran, W. G.
1946. relative accuracy of systematic and stratified random samples for a certain class of populations. Ann. Math. Statis. 17(2): 164-177.

Comparison is made of random, stratified random (one element per stratum) and systematic samples where serial correlation exists. Stratified random samples are at least as accurate as random samples. The comparison of systematic and random samples depends on the form of the population. No unbiased estimate of error can be made from a single systematic sample, nor from a stratified random sample with only one element per stratum.

Conagin, A.
1950. disposicao sistemática dos canteiros. sua influência sôbre a estimative do êrro experimental. (systematic arrangement of trial plots. effect on estimate of experimental error.) Bragantia [Brazil] 10(7): 203-207.

This paper describes the results of superimposing certain types of 5 X 5 Latin squares on a wheat uniformity trial. The purpose was to investigate the bias in the estimate of error when certain systematic squares (knight's move and diagonal) are chosen and to compare the results under conditions in Brazil with those obtained by Tedin in a similar investigation. The following conclusions are drawn: (a) when Latin squares are chosen by a random process, as recommended by Fisher, the observed distribution of the variance ratio of "treatments" compared with error is in agreement with that given by theory; (b) the estimation of error variance is biased when systematic squares are employed. In agreement with Tedin, the author finds that the knight's move square furnishes an overestimate, and the diagonal square an underestimate of error variance. Under the conditions of this trial, the systematic squares suffer from the same disadvantages which have been noted elsewhere.--Auth. sum.

Cousens, J. E.
1958. a study of 155 acres of tropical rain forest by complete enumeration of all large trees. Malayan Forester 21(3): 155-164.

A complete enumeration of all trees over four feet in girth at breast height in 155 acres of virgin forest is described. Floristically the area shows considerable variation, but there is little large-scale variation in structure. Symington's Coastal Hill Forest association appears to be clearly defined. It is shown the systematic sampling at an intensity of 10 percent gives a maximum error of 12.5 percent. Unrestricted random and stratified random samples at 20 percent intensity show somewhat higher maximum errors than systematic sampling. One-chain-wide strips are preferable to wider strips or compact blocks. Recommendations are made for sampling areas of normal compartment size for all species and include the adoption of random sampling and measures to insure an adequate number of strips.--Biol. Abs.

Dawkins, H. C.
1952. experiments in low percentage enumerations of tropical high-forest. Empire Forestry Rev. 31(2): 131-145.

A series of low percentage enumerations in South Mengo, Uganda, was analyzed statistically. It was found that precision, i.e., smallness of sampling errors, depended on density of the population and on the number of samples available. The actual percent of the sample was of little significance compared to its comminution and the density of the observed quantities within it. Sampling errors of less than 20 percent were obtained on populations of more than 2 stems per acre by a 1 percent dispersed-plot enumeration of 7.5 sq. miles of highly variable forest. While dispersed-plot enumerations gave more precise estimates--for equal areas sampled--than transect methods, the relative cheapness of the latter made them more efficient except in special cases. When dealing with areas of 5-15 sq. miles, 2-per-1/2-mile stratified random chainwide transects giving 5 percent coverage are advocated for estimating populations with densities from 1 to 10 stems per acre. For

lower densities or smaller areas higher coverage may be necessary, while with increasing density or area, lower percentage would give tolerable errors. Superimposed dispersed-plot 20 percent samples of the transects were suitable for estimates of populations exceeding 10 per acre, if more than 1 sq. mile was originally covered. All management relying on enumeration results should be based on the lower fiducial limit and not on the mean of the sample. This value is more easily understood as the Reliable Minimum Estimate, a term here suggested for general use in forest sampling.--From auth. sum.

Fortmann, H. R.
1951. observations on "selection" of data. Agron. Jour. 43(11): 560-561. [See NONRANDOM SAMPLING DESIGN]

Greenberg, B. G.
1951. why randomize? Biometrics 7(4): 309-322.

A set of uniformity data on inocula of Trichinella larvae are examined critically for the purpose of comparing the merits of several randomized and systematic experimental designs. Many commonly used systematic designs introduced bias and inflated error estimates. Specific recommendations are made for special cases. Experimental factors which make this problem important are listed and discussed.

Hasel, A. A.
1938. sampling error in timber surveys. Jour. Agr. Res. 57(10): 713-736, illus.

The heterogeneous nature of variation in board foot volume in a 5,760-acre area of pine timber type in northeastern California was shown by use of Fisher's method of analysis of variance. The analyses were based on a 100 percent inventory. The effects upon sampling error of size, shape, arrangement of plots, and intensity of sampling were determined theoretically and checked against actual results from samples taken according to the specifications set up. The smallest size of plot, 2.5 acres, was a more efficient sampling unit than plots of larger size, and long, narrow plots were more efficient than those approaching the square shape. A valid estimate of sampling error was possible only by selecting the sampling units independently and at random. By dividing the area into blocks of uniform size and shape, and selecting equal numbers and at least two random sampling units in each, a significant reduction in error variance was obtained as compared to unrestricted random selection. Cruises with plots arranged in a systematic pattern gave somewhat closer estimates of true volume than did corresponding random cruises, but did not contain the information needed for assessing sampling error. A combination of random and systematic cruising was recommended.--A. A. Hasel.

Hummel, S. C.
1952. an experiment on the sampling of early thinning. Forestry [London] 25(1): 19-31. [See NONRANDOM SAMPLING DESIGN]

Hutchinson, A. H., and Knapp, F. M.
1947. random sampling, planned sampling, and selective sampling: as applied to forest ecology and silviculture. Roy. Soc. Canada, Proc. and Trans., Sect. 5 (1946) 40: 77-79. [See NONRANDOM SAMPLING DESIGN]

Jeffreys, Harold.
1939. random and systematic arrangements. Biometrika 31(1/2): 1-8.

A distinction is drawn between randomness in the design of experiments and randomness in the sense of mutual irrelevance of the errors. The latter is what is needed for the validity of most statistical methods, and is not necessarily improved by the former. Examples are given from various subjects. The author agrees in general with Fisher's recommendation to estimate and eliminate known effects as accurately as possible and randomize the rest.--H. Jeffreys.

Johnson, Floyd Alfred.
1943. a statistical study of sampling methods for tree nursery inventories. Jour. Forestry 41(9): 674-679. [See NONRANDOM SAMPLING DESIGN]

Kaneko, Y., and Kojima, K.
1957. on the method to estimate the number of seedlings in the nursery. Jour. Jap. Forestry Soc. 39(7): 260-266. [In Japanese with English summary.] [See MULTISTAGE AND DOUBLE SAMPLING]

Kirk, L. E.
1929. field plot technique with potatoes with special reference to the latin square. Sci. Agr. [Ottawa] 19: 719-729.

Latin-square layout gave a 27 percent lower probable error than systematic arrangement. Increased replication is twice as efficient as larger sized plots.

Neyman, Jerzy.
1934. on the two different aspects of the representative method: the method of stratified sampling and the method of purposive selection. Roy. Statis. Soc. Jour. 97(4): 558-625, illus.

In planning an investigation of a population by sampling, the samples may be chosen in two different ways: (1) at random either from the

population as a whole or from each of several strata into which it is divided (stratified sampling). It is often convenient to choose for each sample a group of individuals, e.g., a census district. (2) Groups are chosen so that the weighted mean of some control character, y, known for the whole population and assumed to be linearly correlated with the character x to be investigated, has the same value as in the total population (purposive selection). Bowley's estimate of the mean of x is inconsistent. (In the discussion Bowley pointed out that Neyman had misunderstood his method, which is really consistent). The method of Gini and Galvani is consistent if the regression of x on y is linear not only for the whole population but for each group of districts composed of a fixed number of individuals. The applicability of this hypothesis can only be tested by an extensive inquiry. On the other hand the method of stratified sampling does not depend on any hypothesis about the stratified population and is therefore preferable except in special cases. If groups are used as elements of sampling they should be as small as possible.--Biol. Abs.

Neyman, J., and Pearson, E. S.
1937. note on some points in "student's" paper on "comparison between balanced and random arrangements of field plots." Biometrika 29(3/4): 380-388. [See NONRANDOM SAMPLING DESIGN]

Osborne, James G.
1942. sampling errors of systematic and random surveys of cover-type areas. Amer. Statis. Assoc. Jour. 37(218): 256-264, illus. [See NONRANDOM SAMPLING DESIGN]

Pearson, E. S.
1938. some aspects of the problem of randomization. II. an illustration of "student's" inquiry into the effect of "balancing" in agricultural experiments. Biometrika 30(1/2): 159-179, illus. [See NONRANDOM SAMPLING DESIGN]

Pechanec, Joseph F.
1941. sampling error in range surveys of sagebrush-grass vegetation. Jour. Forestry 39(1): 52-54.

One major objective of a range survey is to determine the forage cover, as a basis on which to estimate grazing capacity. However, it is extremely unlikely that the estimated forage yield of an area will coincide with the actual yield, even if methods of measuring vegetation are without error, and if individual members of survey crews are mechanical in their precision. If sampling units are drawn correctly, however, an estimate of the magnitude of the difference between the estimated and actual yield and the likelihood of the occurrence of such difference is provided by the unbiased estimate of sampling error. An unbiased or representative estimate of sampling error also provides

appropriate information for estimating the number of sampling units (plots) needed to attain arbitrary limits of accuracy in future surveys on similar range areas.--Auth. sum.

Pechanec, Joseph F., and Stewart, George.
1941. sagebrush-grass range sampling studies: variability of native vegetation and sampling error. Amer. Soc. Agron. Jour. 33(12): 1057-1071.

Variability of native sagebrush-grass range vegetation was studied at the U.S. Sheep Experiment Station near Dubois, Idaho. The sagebrush-grass type is a heterogeneous plant community, composed of species that are highly variable in abundance and whose frequency distributions are strongly skewed to the left. Subdivided random sampling, using line-plot sampling units, is as easily used as systematic sampling and increased the information secured by 1.31, 0.61, and 1.08 units, respectively, for the 3 major plant species over the information that might have been secured with strictly random sampling. To provide data reliable enough for studies of plant succession, indicator species or poisonous plants, sampling intensity should be determined with full cognizance of the higher variability of secondary species. No acceptable standard of accuracy can be set for sampling but certain intensive vegetation studies may require sampling sufficiently intense to provide a sampling error of 5 percent for the major species and class totals and 10 percent for secondary species.--J. F. Pechanec.

Salmon, S. C.
1953. random versus systematic arrangement of field plots. Agron. Jour. 45(10): 459-462. [See NONRANDOM SAMPLING DESIGN]

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1955. random versus systematic in non-latin square field experiments. Agron. Jour. 47(7): 289-294. [See NONRANDOM SAMPLING DESIGN]

Singh, D.
1956. on efficiency of cluster sampling. Indian Soc. Agr. Statis. Jour. 8(1/2): 45-55.

Smith, H. Fairfield, and Myers, C. H.
1934. a biometrical analysis of yield trials with timothy varieties using rod rows. Amer. Soc. Agron. Jour. 26(2): 117-128.

In comparative tests of varieties of timothy by use of broadcast plots and by rod rows, the yields agreed to the extent expected in regard to the experimental errors. The disadvantage of systematic as compared to randomized arrangement is well illustrated. Methods of adjusting varietal yields are discussed. The use of a theoretical or graded

check in this case is deemed appropriate. An application is made of Fisher's analysis of variance to yields adjusted by relation to the checks. The relation of parts in the analysis of variance to some of the older statistics used in estimating error is indicated.

"Student."
1937. comparison between balanced and random arrangements of field plots. Biometrika 29(3/4): 363-379. [See NONRANDOM SAMPLING DESIGN]

Tedin, O.
1931. the influence of systematic plot arrangements upon the estimate of error in field experiments. Jour. Agr. Sci. 21: 191-208.

Effect of systematic plot distribution upon the estimate of error of a 5 X 5 field experiment was studied on 91 blocks taken from different uniformity trials. Two different knight's moves, two diagonal, and seven random arrangements were studied. Knight's move arrangements cause an overestimation of error. Diagonal arrangements cause an underestimation of error. In one individual experiment it may be desirable to use a systematic arrangement but where experiments are to be repeated frequently the experimenter will find it desirable to choose random arrangements. Ratio of error to total error in uniformity trials: knight's moves--22.77 and 22.83; diagonals--26.24 and 27.94; random--25.25, 20.91, 23.93, 27.45, 25.25, 22.94, 23.16 and 25.69. Author believes that choice of a method of arrangement should consider accuracy of methods, increase in labor, and other factors, as well as the small increased accuracy due to elaborate experimental arrangements and intensive analysis should be considered.

Yates, F.
1938. the comparative advantages of systematic and randomized arrangements in the design of agricultural and biological experiments. Biometrika 30(3/4): 440-466, illus.

The recent claims advanced in favor of systematic arrangements by Gosset ("Student") and others are examined. The conclusion is reached that in cases where Latin square designs can be used, and in many cases where randomized blocks have to be employed, the gain in accuracy with systematic arrangements is not likely to be sufficiently great to outweigh the disadvantages to which systematic designs are subject. In particular the available evidence, though not conclusive, indicates that the half-drill strip arrangement, which Gosset particularly favored, is likely to be somewhat less accurate than suitable random arrangements occupying the same plots. On the other hand, systematic arrangements may in certain cases give decidedly greater accuracy than randomized blocks, but it appears that in such cases the use of the modern devices of confounding, quasi-factorial designs, or split-plot Latin squares is likely to give a similar gain in accuracy, and is much more satisfactory

statistically. As an example the uniformity trial chosen by Barbacki and Fisher to demonstrate the defects of the half-drill strip arrangement is reexamined. Gosset's criticisms of Barbacki and Fisher's work, though at first sight convincing, are not as conclusive as he supposed, and this particular trial provides a striking example of just those defects which have always been attributed to the half-drill strip methods by its critics.--F. Yates.

Yates, Frank.
1949. sampling methods for censuses and surveys. New York: Charles Griffin, 318 pp., illus.

In writing a manual to assist in the projected 1950 World Census of Agriculture and 1950 World Census of Population, the author attempts to cover all the modern developments of sampling theory of importance in census and survey work. In the orderly development of the manual from a discussion of the place of sampling in census work, through requirements and structure of samples, problems in planning, execution, and analysis of a survey, and estimation of the population values and sampling error, to efficiency, a number of gaps in current theory had to be filled in. Contains a bibliography of 373 items classified under 10 headings.

Bose, C., and Gayen, A. K.
1946. note on the expected discrepancy in the estimation (by double sampling) of a variate in terms of a consistent variate when there exists a non-linear regression between the two variates. Sankhyā: Indian Jour. Statis. 8(1): 73-74.

Results obtained by one of the authors, Mrs. C. Bose, in a previous paper for double sample where there is a linear relation between a variate y, difficult or expensive to measure, and a correlated variate x, easier or less expensive to measure, are extended to the case where there is a correlation between y and x of the non-linear type $y=ax^b$.

Ecimovic, J. P.
1956. three-stage sampling with varying probabilities of selection. Indian Soc. Agr. Statis. Jour. 8(1/2): 14-44.

Kaneko, Y., and Kojima, K.
1957. on the method to estimate the number of seedlings in the nursery. Jour. Jap. Forestry Soc. 39(7): 260-266. [In Japanese with English summary.]

In the estimation of the number of the seedlings in the nurserybed of one-year seedlings of Chamaecyparis obtusa, the degree of accuracy among four methods applied lined up as: stratified two-stage sampling (the primary sampling unit was the stratum), stratified one-stage sampling, random sampling, and cluster sampling. Even with stratified two-stage sampling, if the primary sampling unit was the cluster, the accuracy of estimation was inferior to the one with stratified one-stage sampling. Number of sampling unit for obtaining given degrees of accuracy was shown. The comparison between random sampling and purposive selection is also shown.--Biol. Abs.

Petersen, R. G., and Chamblee, D. S.
1955. optimum size of sample for hand separation of forage crop mixtures into their component species in small plot experiments. Agron. Jour. 47(1): 20-23.

The botanical composition of two experiments uniformly seeded to a mixture of legumes and grasses was estimated by hand separating subsamples of the fresh forage from the yield-strip sample (2 X 23 feet). The optimum size of sample, $s_{opt.}$, was estimated using the following formula:

$$s_{opt.} = \sqrt{\frac{C_r \sigma_s^2}{C_s \sigma_r^2}}$$

in which C_r is the most associated with each plot, C_s is the cost

associated with each hand separated sample, σ_s^2 is the sample to sample variation, and σ_r^2 is the variation between plots treated alike. With the plot size used in this study the most efficient size of subsample for estimating botanical composition by hand separating was found to be approximately ten percent.

Rao, J. N. K., and Chawla, H. K.
1956. efficiency of stratification in subsampling designs for the ratio method of estimation with varying probabilities of selection. Indian Soc. Agr. Statis. Jour. 8(1/2): 91-101.

Schumacher, F. X., and Chapman, Roy A.
1942. sampling methods in forestry and range management. Duke Univ. Forestry Bul. 7, 213 pp., illus.

Problems in sampling of forest and field populations, leading to estimates of averages and aggregates, are discussed in the light of case studies. Emphasis is upon striving for maximum information, such that the unknown discrepancy between a population characteristic which is the subject of inquiry and the sampling estimate thereof may be (1) evaluated unambiguously, and (2) made as small as possible, subject to the ever-present limitations of time and funds available for the work. The theory and practice of representative sampling, subsampling, and double sampling are treated in some detail.

Seelbinder, B. M.
1953. on stein's two-stage sampling scheme. Ann. Math. Statis. 24(4): 640-649.

This refers to preliminary sampling for variance, to decide the number needed in the total sample. This will depend on the significance level (α), and the allowable discrepancy (d) in estimate of the mean. The N, (preliminary sample size), to minimize total work has been based on the incomplete gamma function; an approximation using the normal distribution is developed. Tables are presented for choice of N_1, for various values of α, and d taken in terms of standard deviation. An example from Cochran's data is presented, and five references are cited.

Sukhtame, P. V.
1950. efficiency of sub-sampling designs in yield surveys. Indian Soc. Agr. Statis. Jour. 2(2): 212-228.

A general formula appropriate for the estimation of gains in precision due to stratification in a sub-sampling design from finite population has been developed and illustrated on the yield data relating to sample surveys carried out in Delhi Province during 1946-1947, 1947-1948, and 1948-1949. Formulae appropriate for (a) no sub-sampling and (b)

sub-sampling with a uniform sampling fraction at the first stage are shown to be particular cases of the general formula. Based on the same results, an approach has been indicated for calculating the relative efficiency of sampling units of different size and of one- versus two-stage sampling and the method illustrated on the yield data for Delhi Province.--Auth. sum.

Wilm, H. G., Costello, David F., and Klipple, G. E.
1944. estimating forage yield by the double-sampling method. Amer. Soc. Agron. Jour. 36(3): 194-203.

Two double-sampling methods, using line-transects and forage weight estimates for the large samples and actual weights of clipped forage for the small samples, were tested to ascertain their relative efficiency in estimating the amount of forage present on experimental areas in Colorado. Double sampling with the line-transect method provided about 28 percent more information than could have been obtained by clipping only, during the same period of field time. About 11 percent more information was obtained when time expended in both field and office was considered. When weight estimates were used in double sampling, 37 percent more information was obtained than would have been provided by straight clipping during an equivalent amount of field time. Considering both field work and office compilation the gain in information dropped to about 14 percent. With the intensive sampling used in this study both methods provided substantial savings in field time and some economy in total time expended. The study indicated, however, that clipping of all plots might be as efficient as any short-cut method in large-scale extensive surveys where time consumed in field travel is a major factor.--From auth. sum.

Barbacki, S., and Fisher, R. A.
1936. a test of the supposed precision of systematic arrangements. Ann. Eugenics [Cambridge] 7: 189-193. [See RANDOM SAMPLING DESIGN]

Baten, William D., Arend, John L.
1954. a laboratory study of various systematic sampling methods applicable to forest-regeneration surveys. Mich. Acad. Sci., Arts and Letters, Papers 39: 113-123, illus.

The paper reports on the reliability of estimates obtained from applying 25 systematic sampling methods that might be used in forest-reproduction surveys to one artificially created seed pattern of known distribution. Since it is almost impossible to count and map all tree seedlings on a forest tract in order to have a known quantity and distribution as a basis for appraising the reliability of different methods and intensities of sampling, an artificial distribution was created in the laboratory for study. The tests revealed that when only 1 percent of the area is sampled, only one-half of the estimates of the total number may be within 50 percent of the actual number. Estimates of the number of seedlings should be based on sampling more than 4 percent of the area, for with a smaller sample no particular sampling design or sample-plot arrangement can be expected to provide reliable estimates of quantity. Fairly dependable estimates of the percentage of plots stocked with one or more seedlings appear to be possible when as little as 2 percent of the area is sampled. Offsetting a continuous series of 5 or 10 plots diagonally across the sample population may be a sampling method to consider in forest reproduction surveys.--Biol. Abs.

Bourdeau, Philippe F.
1953. a test of random versus systematic ecological sampling. Ecology 34(3): 499-512. [See RANDOM SAMPLING DESIGN]

Cochran, W. G.
1946. relative accuracy of systematic and stratified random samples for a certain class of populations. Ann. Math. Statis. 17(2): 164-177. [See RANDOM SAMPLING DESIGN]

Cousens, J. E.
1958. a study of 155 acres of tropical rain forest by complete enumeration of all large trees. Malayan Forester 21(3): 155-164. [See RANDOM SAMPLING DESIGN]

Craig, A. T.
1939. on the mathematics of the representative method of sampling. Ann. Math. Statis. 10: 26-34.

Fortmann, H. R.
1951. observations on "selection" of data. Agron. Jour. 43(11): 560-561.

The mean squares for three types of samples (N=200) selected at random from a restricted population of 200 variants were determined. The average mean square for samples consisting of means of duplicate determinations was some 21 percent lower (theoretical expectation = 28 percent lower) than the average mean square for samples consisting of the means of the two closest of three observations. The results illustrate that, on the average, "selection" of data from multiple determinations of unknown quantities leads to less accurate estimates than "unselected" data.--H. R. Fortmann.

Greenberg, B. G.
1951. why randomize? Biometrics 7(4): 309-322. [See RANDOM SAMPLING DESIGN]

Hasel, A. A.
1938. sampling error in timber surveys. Jour. Agr. Res. 57(10): 713-736, illus. [See RANDOM SAMPLING DESIGN]

Hasel, A. A.
1942. sampling error of cruises in the california pine region. Jour. Forestry 40(3): 211-217, illus.

The timber on 31 20-acre blocks was inventoried in small units. Stands containing heavy volumes generally require less sampling than lighter stands for the same degree of accuracy. Curves of variance provide a basis for estimates of sampling accuracy in systematic cruises. The size of the area to which cruise estimates apply has a marked effect upon sampling error.

Hummel, S. C.
1952. an experiment on the sampling of early thinning. Forestry [London] 25(1): 19-31.

Several subjective and objective methods of sampling the average volume per tree in the first and second thinnings were tested in stands of Sitka spruce, Norway spruce, Scotch pine, Corsican pine, Douglas fir, and European larch. Altogether 7,000 trees were measured. The subjective methods, consisting of visual estimates and a measurement of groups of trees selected as representative, tended to give biased results. The objective methods tested were random groups, systematic

sampling by trees, and systematic sampling by rows. Systematic sampling by rows appeared to be the most satisfactory since it combined a reasonable degree of precision with simplicity in execution.

Hutchinson, A. H., and Knapp, F. M.
1947. random sampling, planned sampling, and selective sampling: as applied to forest ecology and silviculture. Roy. Soc. Canada Proc. and Trans., Sect. 5 (1946) 40: 77-79.

An ecological survey of the University of British Columbia Forest Reserve is in progress, under the British Columbia Industrial and Scientific Research Council. Selection of sample plots on a basis of ecological contours has been adopted. Lines paralleling and running at right angles to contours are chosen. Contours may be the margin of the forest bordering a logged area, the topographical slope, or the light, humidity, or temperature contours. In this way the factors of distribution of seedlings may be evaluated.--Auth. abs.

Jeffreys, Harold.
1939. random and systematic arrangements. Biometrika 31(1/2): 1-8. [See RANDOM SAMPLING DESIGN]

Johnson, Floyd Alfred.
1943. a statistical study of sampling methods for tree nursery inventories. Jour. Forestry 41(9): 674-679.

Tree counts were made on systematic, random, and stratified-random sampling units in drill-sown, broadcast, and transplant nursery beds. Samples consisted of 1-, 2-, and 3-ft. lengths of single rows, and of ½-, 1-, 1½-, 2-, and 3-ft. bed lengths across beds 52 in. wide. Completely random samples were less accurate than stratified-random samples. Where no estimate of sampling error was required, systematic sampling was superior to stratified-random sampling of seedbeds; in transplant beds the two methods were equally accurate. The relation of sampling efficiency to size of sampling unit varied with species and class of stock, but the smaller units were usually best. The statistical relation between intensity and accuracy of sampling in forest nurseries is discussed.--Biol. Abs.

Kirk, L. E.
1929. field plot technique with potatoes with special reference to the latin square. Sci. Agr. [Ottawa] 19: 719-729. [See RANDOM SAMPLING DESIGN]

Neyman, Jerzy.
1934. on the two different aspects of the representative method: the method of stratified sampling and the method of purposive selection. Roy. Statis. Soc. Jour. 97(4): 558-625, illus. [See RANDOM SAMPLING DESIGN]

Neyman, J., and Pearson, E. S.
1937. note on some points in "student's" paper on "comparison between balanced and random arrangements of field plots." Biometrika 29(3/4): 380-388.

This paper gives some fuller explanation of certain points in "Student's" paper which, it was known, he had intended to revise.--Biol. Abs.

Osborne, James G.
1942. sampling errors of systematic and random surveys of cover-type areas. Amer. Statis. Assoc. Jour. 37(218): 256-264, illus.

To estimate the composition of an area by cover-type classes, sampling is usually systematic, the national forest-survey procedure being one line in 10 miles of width. By superimposing on a map 20 lines per mile, randomly placed, three types of sampling were tried: completely random, stratified random, and a systematic type consisting of lines one mile apart. The estimates of the mean area in cultivated land were practically the same in the three types of sampling, but the stratified random surveys were only ½ to ¼ as efficient as systematic surveys of the same intensity. The nature of the variation found in populations in place is such that the variate measured may be considered as a continuous function of position and the problem of sampling reduces, sensibly, to one of curve fitting. A polynomial of sixth degree was fitted to the variate, number of chains of cultivated land, and formulas developed for estimating the error of predicting the mean of another survey. If data taken in the systematic manner investigated are used with random sampling formulas, biased estimates of the sampling errors result; but from estimates of the correlation of measured and unmeasured lines dependable estimates of the sampling errors of this kind of systematic samples are obtained.--Biol. Abs.

Pearson, E. S.
1937. some aspects of the problem of randomization. Biometrika 29(1/2): 53-64.

———— 1938. some aspects of the problem of randomization. II. an illustration of "student's" inquiry into the effect of "balancing" in agricultural experiments. Biometrika 30(1/2): 159-179, illus.

This paper discusses in some detail one aspect of the problem dealt with in "Student's" (the late Mr. W. S. Gosset's) last paper. The main point in question was that in agricultural experiments "balanced" arrangements would have the following advantage over "random" arrangements: While being less likely to detect the presence of small differences, they would seem to be somewhat more likely to detect the larger and therefore more important differences. The author of the paper

expresses the position in algebraic form, relating it to certain theoretical work of Neyman and Pearson concerning the "power" of the test of a statistical hypothesis. He also makes further use of A. W. Hudson's uniformity trial data, quoted by "Student."--E. S. Pearson.

Pechanec, Joseph F., and Stewart, George.
1941. sagebrush-grass range sampling studies: variability of native vegetation and sampling error. Amer. Soc. Agron. Jour. 33(12): 1057-1071. [See RANDOM SAMPLING DESIGN]

Rao, J. N. K.
1958. partially systematic line-plot surveys. Indian Forester 84(7): 424-427.

Salmon, S. C.
1953. random versus systematic arrangement of field plots. Agron. Jour. 45(10): 459-462.

A critical review of and a reinterpretation of the literature plus additional data by the author leads to conclusion that random arrangements of field plots often results in substantial increases in the real error and in such cases cannot be justified. Such arrangements may be desirable for theoretical statistical studies using data from field experiments and in certain practical experiments in order to protect the investigator against charges of or suspicion of bias. In many experiments, mostly seeded or harvested by hand, plots may be arranged randomly or systematically according to the taste or preference of the experimenter providing he is certain that randomization does not introduce important sources of error.--S. C. Salmon.

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1955. random versus systematic in non-latin square field experiments. Agron. Jour. 47(7): 289-294.

"Random" and "good" systematic arrangements were compared with respect to "treatment" and error variances for 113 separate and distinct hypothetical experiments superimposed on uniformity data for 27 different locations and 14 different crops in the United States and Canada. The study involved 7,155 plot yields and 5,238 individual plots of land. "Treatment" variances for the systematic arrangements averaged 80 percent of those from random arrangements meaning that about one-fourth more replications would be required with random arrangements to assure the same degree of accuracy of mean yields as would be expected from "good" systematic arrangements.--S. C. Salmon.

Smith, H. Fairfield, and Myers, C. H.
1934. a biometrical analysis of yield trials with timothy varieties using rod rows. Amer. Soc. Agron. Jour. 26(2): 117-128. [See RANDOM SAMPLING DESIGN]

"Student"

1937. comparison between balanced and random arrangements of field plots. Biometrika 29(3/4): 363-379.

This paper is concerned with the statistical basis underlying the interpretation of results obtained in agricultural experimentation. In "Student's" view, the advantages of randomly assigning to plots the treatments or varieties under consideration are usually offset by an increased error, as compared with a balanced assignment. In this view he had been vigorously opposed by R. A. Fisher, and the first object of the paper is to set out as clearly as possible in what this difference consists. After clearing away certain misrepresentations concerning the half-drill strip method of comparing two varieties, "Student" illustrates some of his points on a new type of balanced layout which he describes as a chess-board with fringes. Finally he shows how, when real treatment or variety differences exist, the balanced lay-out, while it will not detect small differences, is somewhat more likely to detect large differences than a random lay-out. He considers that in this sense the former procedure is more, not less valid than the latter. These ideas are illustrated on some statistical analyses carried out by Mr. A. W. Hudson on uniformity trial data, details of which are given in an Appendix.--Biol. Abs.

Tedin, O.

1931. the influence of systematic plot arrangements upon the estimate of error in field experiments. Jour. Agr. Sci. 21: 191-208. [See RANDOM SAMPLING DESIGN]

Yates, F.

1938. the comparative advantages of systematic and randomized arrangements in the design of agricultural and biological experiments. Biometrika 30(3/4): 440-466, illus. [See RANDOM SAMPLING DESIGN]

II. DESIGN OF EXPERIMENTS

1. GENERAL

Bailey, G. L., Broster, W. H., and Burt, A. W. A.
1958. experiments on the nutrition of the dairy heifer. II. experimental methods in short-term experiments. Jour. Agr. Sci. [England] 50(1): [1]-7.

1. Data from twenty-four short-term trials on the nutrition of dairy heifers have been used in a study of the effects of management, method of estimation of live-weight gain, length of experimental period, covariance analysis and the use of monozygous twins upon experimental error. 2. The value of rigid adherence to a routine and allowing ample time for the animals to settle down before the trial have been demonstrated. 3. Error standard deviations were associated with length of experimental period, those for 42-day periods being about half those per 21-day periods, but were not appreciably correlated with initial live weight. 4. No advantage could be demonstrated for the use of monozygous twins, or covariance analysis with initial weight or rate of gain, indicating that genetic effects contributed little to the error in experiments lasting 3-6 weeks. 5. There was no significant difference between errors in live-weight gains calculated from the regression of live weight on time, from single initial and final weights, or from two initial and final live weights, indicating that deviations from linear regression are not solely in the nature of random day to day fluctuations in live weight.--Auth. sum.

Baker, G. A., and Roessler, E. B.
1957. implications of a uniformity trial with small plots of wheat. Hilgardia 27(5): 183-188.

A field trial with small plots of wheat, which can be regarded as a uniformity trial, is presented. This trial was examined in a manner similar to that used on other field trials, with very contrasting results. Results of randomization trials in other studies have differed markedly from the conventional published analysis-of-variance tests based on the F tables. However, this trial, although judged by experienced investigators because of weed infestation, soil variation, and stand variation, seems to correspond very closely in many important respects to the model and to resulting tests given in the textbooks.--Biol. Abs.

Beall, Geoffrey.
1940. the technique of randomization in field work. Canadian Ent. 72(3): 45-48.

Outlines a method of theoretically perfect randomization, illustrated by tables and figures, for use in any experimental problem, necessitating randomization of samples or plots.

Behrens, W. H.
1956. feldversuchsanordnungen mit verbessertem ausgleich der bodenunterschiede. [the arrangement of field experiments with improved compensation for soil variations.] Ztschr. f. Landw. Vers. u. Untersuchw., Rostock 2(3): 176-193, illus.

Belz, Maurice H.
1957. common errors in obtaining and evaluating experimental data. Phys. in Med. and Biol. 2(1): 3-16.

The paper reviews the contribution which statistics and statisticians can make to the design of experiments and the analysis of experimental results in biology and medicine. An account is given of the principles of factorial experiments, in which, with maximum economy of experimentation, information may be obtained on the main effects of a number of individual factors as well as their interactions in an experimental system. The planning of experiments from the point of view of the number of observations necessary to obtain the required information is discussed, particular reference being made to the advantages and disadvantages of the sequential method of planning. Common errors and misunderstandings in the study of regression and correlation and the use of significance testing are described and discussed.--Auth. sum.

Bradley, R. A., and Schumann, D. E. W.
1957. the comparison of the sensitivities of similar experiments: applications. Biometrics 13(4): 496-510.

Brandt, A. E.
1937. factorial design. Amer. Soc. Agron. Jour. 29: 658-667.

Shows how, in factorial experiments, single degrees of freedom are applied to single treatments and interactions. Makes χ^2 test for homogeneity of variances before pooling into one error term. Discusses factorial design in two experiments and describes an application of split-plot design to one of them.

Calzada Benza, J.
1957. el error experimental y la precision en los experimentos. Lima, Peru, Estac. Expt. Agr. de La Molina, Bol. 67, 33 pp. [English summary.]

Capó, Bernardo G.
1944. a new method of performing field trials. Jour. Agr. Univ. Puerto Rico 28(1): 22-34.

A description is given of a new method of performing experiments with small numbers of treatments. The author applies the method to the interpretation of a fertilizer experiment.

Carlson, I. T., and Moll, R. H.
1959. an analysis of variability in quantitative characters in strains of orchardgrass. Agron. Abs. 1959:54.

Christidis, Basil G.
1935. intervarietal competition in yield trials with cotton. Jour. Agr. Sci. [England] 25: 231-238.

Competition may cause a definite bias in estimating the comparative yielding value of cotton varieties. Therefore, it appears advisable that field trials should be so arranged that competition effects between different varieties will be eliminated.

Cochran, W. G.
1937. catalogue of uniformity trial data. Roy. Statis. Soc. Jour. 4(2): 233-253.

Catalogue showing where uniformity trial data has been collected, whether published with paper and if not, where filed. Entries classified by crops. Only one entry for pasturage.

_______, and Cox, Gertrude M.
1957. experimental designs. Ed. 2, New York: 611 pp., illus. John Wiley and Sons, Inc.

The second edition of this well recognized test on experimental design brings the subject more up to date. It incorporates new material on fractional replication in factorial experiments. Factorial methods are discussed in which the response to the levels of the factors is represented by some mathematical function. Methods for obtaining the levels at which the factors must be set in order to obtain maximum response are introduced. New incomplete block designs are presented together with references to many more that are now available. Newer methods for analyzing discreet data for completely randomized and randomized block designs are considered. Other problems, less exhaustively discussed, are those of sequential experimentation, newer significance tests, errors in recovery of inter-block information, etc. The text follows the general arrangement of the first edition. The subject matter is divided into 17 chapters, a selected bibliography, list of author references, index and tables of t and F. The first chapters

deal with methods for increasing the accuracy of experiments; notes on statistical analysis; designs of randomized, randomized block and latin square arrangements; factorial experiments; confounding; factorial experiments in fractional replication; main effects confounded; split plot designs and confounded quasi-latin squares. Later chapters consider methods for study of response surfaces; incomplete block designs; lattice designs; balanced and partially balanced incomplete block designs; lattice squares and incomplete Latin squares; analysis of results of a series of experiments; and random permutations of 9 and 16 numbers. The second edition promises to be every bit as important as the first in furthering knowledge of experimental design. --Biol. Abs.

Crampton, E. W.
1942. the design of animal husbandry experiments. Jour. Anim. Sci. 1(4): 263-276.

This is chiefly a general discussion of the application of factorial design to certain types of animal husbandry experiments. Statistical analysis of data is undertaken partly to more accurately and conveniently describe a mass of otherwise unintelligible figures. This may be as important as its objective of establishing significance of the results found. Factorial design violates the principle of varying but one thing at a time in experimentation. This principle does not permit of as comprehensive an interpretation of the results as is possible with modern trial-design and subsequent statistical analysis. Loss of precision through studying with the same group of animals several experimentally imposed conditions is less than has often been supposed, and may be negligible. The application of factorial design is illustrated by pig-feeding trials at Macdonald College.--Biol. Abs.

Crowther, E. M.
1936. the technique of modern field experiments. Roy. Agr. Soc. England Jour. 97: 54-80.

Daniel, H. A., Cox, Maurice B., Tucker, Billy B., and others.
1957. design of plots conforming to the land for evaluating moisture conservation practices. Soil Sci. Soc. Amer. Proc. 21(3): 347-350.

Dembiczak, C. M., Eaton, H. D., Beall, G, and others.
1957. design and conduct of calf nutrition studies. I. one- vs. two- and three-day growth measurements. Jour. Dairy Sci. 40(9): 1133-1151.

Dunlop, George.
1933. methods of experimentation in animal nutrition. Jour. Agr. Sci. [England] 23(4): 580-614.

The unsatisfactory nature of methods adopted in feeding experiments at animal nutrition research institutes is due to neglect of the worker to control variable factors, other than those being investigated, which affect growth rate. It is proved that age, sex (females and castrated males), condition, and previous growth rate have no effect on rate of live-weight increase of swine in the Cambridge University herd, and the basis on which animals are allotted to groups to ensure homogeneity is fallacious. Merits and drawbacks of different methods in animal feeding experiments are discussed. A new method involving individual rationing, random distribution of animals for statistical analysis of results, and eliminating variability due to controllable factors which must remain uncontrolled in other methods is described, and its precision, accuracy, and sensitivity is 16 times greater than the group-feeding method. A table showing the precision of methods at various centers demonstrates that the precision of any given method is approximately the same at all centers. A standard technique for feeding experiments is described, suitable for adoption elsewhere.--Auth. sum.

Finney, D. J.
1957. stratification, balance and covariance. Biometrics 13(3): 373-386. [See COVARIANCE ANALYSIS]

Fisher, R. A.
1935. the independence of experimental evidence in agricultural research. Third Internatl. Cong. Soil Sci. Trans. 2: 112-119.

The paper discusses the logical meaning of "control" as used in experimentation; and, in quantitative experiments, the need, if the experiment is to be self-sufficient, of its supplying the means of making a valid estimate of the errors, to which the results are subject. This may be achieved only by randomization. The purpose of randomization is not to diminish the experimental error, but to afford a valid estimate of it. It is, however, consistent with all the different means and devices by which the experimental error may be diminished. The idea of increasing the precision at the expense of abandoning randomization is always illusory.--Biol. Abs.

Forester, H. C.
1937. design of agronomic experiments for plots differentiated in fertility by past experiments. Iowa Agr. Expt. Sta. Res. Bul. 226, 29 pp.

Garber, R. J., and Hoover, M. M.
1930. persistence of soil differences with respect to productivity. Amer. Soc. Agron. Jour. 22: 883-890.

"Natural differences in productivity of plots persisted over a period of five years, even though these plots were subjected to different treatments."

Geidel, H.
1957. zum ausgleich von bodenunterschieden bei blockanlagen. [balancing out soil differences in block layouts.] Ztschr. f. Acker- u. Pflanzenbau [Berlin] 103(1): 71-82.

Goulden, C. H.
1931. modern methods of field experimentation. Sci. Agr. [Ottawa] 11: 681-701.

A statistical study presenting the methods of conducting field experiments evolved at Rothamsted.

Kalamkar, R. J.
1932. a study in sampling technique with wheat. Jour. Agr. Sci. [England] 22: 783-797.

Yield analyses from a uniformity trial where wheat from a plot 40.6 by 60 links, comprised of 80 rows, was harvested in row half-meter lengths. Analysis of the data indicated significantly higher yields on border plots and on end sections of the rows. Eliminating the border rows and end half-meter of each row, there were 1,092 yields left upon which to test yield sampling methods. Sampling units of four half-meter lengths arranged in five different ways were used as follows:

(1) (2) (3) (4) (5)

In every case except with method (1), the sampling error between samples was greater than within. Effect of competition between rows is offered as an explanation for the superiority of method (1). A slight advantage is gained by the subdivision of the area to be sampled. Eighteen units arranged as in (1) gave a sampling error of five percent on 1/40-acre plots.

Kincaid, C. M., Litton, George W., and Hunt, R. E.
1945. some factors that influence the production of steers from pasture. Jour. Anim. Sci. 4(2): 164-173.

A 2 X 3 X 4 factorial design was used to measure the effect of age, winter feeding level and summer grazing rate on the gain in weight and carcass grade of steers fattened on pasture. No significant difference in gain occurred between yearling and two-year-old steers, but the latter were significantly fatter, the carcass grades being "good"

and "high good," respectively. Each pound of weight gained in the winter feeding period reduced summer gains by 0.58 lb. and increased annual gains by 0.42 lb. Increasing the amount of pasturage from 1-1/3 to 3-2/3 acres per steer increased gains by 19.6 lb. for each added acre. No advantage resulted from withholding animals from part of the pasture until July. In a discussion of the factorial design for experiments with large animals it is suggested that this design offers possibilities for efficient use of experimental material without appreciable loss in precision. The animals used in this trial gave information on three factors and also the interactions between them which was only 3 percent less precise than if they had been used to study one factor alone.

Lucas, H. L.
1956. switchback trials for more than two treatments. Jour. Dairy Sci. 39(2): 146-154.

To take better advantage of the high sensitivity of switch-back or double-reversal trials commonly used to compare two treatments and which have been extended to permit the comparison of three or more treatments, certain convenient and useful features have been added. Designs are given for 3, 4, 5, 6, 7, and 9 treatments. The statistical analysis is outlined symbolically and is illustrated numerically with uniformity data. Missing value formulas are given.--Auth. sum.

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1959. experimental designs and analyses for feeding efficient trials with dairy cattle. In nutritional and economic aspects of feed utilization by dairy cows. Hoglund, C. R., ed., pp. 177-192. Ames: Iowa State Col. Press.

Lynd, J. Q., Graybill, F., and Totusek, R.
1956. factors affecting results of grazing trials with yearling steers. Agron. Jour. 48(8): 352-355, illus.

Evaluation of factors affecting steer performance used in pasture experiments are presented for three uniform herds. Coefficients of variation increased through the wintering period and decreased through the following grazing periods. There was no relation between initial weight and total gain. No significant correlation was indicated between winter gain and corresponding pasture gains. Keratitis, wart virus and internal parasite egg count of fecal samples were not related to gains of treated steers.--Auth. abs.

_______, _______, and _______.
1957. grazing trial evaluations using paired pastures with yearling steers. Agron. Jour. 49(9): 488-492.

The results are given of studies during three years on Bermuda grass [Cynodon dactylon] / legume pastures, established on different soil types. Each pasture was split into two halves. Yearling hereford steers were selected for uniformity during the winter previous to the grazing trials. Those steers which had the least deviation from the mean weight and winter-liveweight gain of the herd were designated as "tester" steers. These steers were paired on the basis of size and winter-liveweight gain and one steer from each pair grazed one half and the other steer grazed the other half of the same split pasture. The "tester" steers remained, each on their own half-pastures, for the whole grazing season. Stocking rates were adjusted to utilize the full estimated stocking capacity of the pastures by introducing so-called "grazer" steers. These were introduced as required during the early part of the season and removed again as pasture production declined. Pasture production, expressed as live-weight gain of tester plus grazer steers, was affected more by soil type than by manurial treatment or method of application. Liveweight gains per head of grazer and tester steers were similar. Gains of tester steers were relatively uniform between the halves of split pastures and between different pastures in given years. The combined, pooled variation between paired steers for all pastures during the three trial years was 17.86, with a coefficient of variability of 12.3 percent. It was thought that the use of paired pastures was of value for the statistical evaluation of pasture production where variations between animals grazing different pastures, or different halves of the same pastures, were minimized. The use of paired tester steers reduced the variation between animals. The effectiveness of the procedures described is dependent on: (a) the use of uniform animals; (b) the use of a preliminary wintering period in order to evaluate individual animal performance; and (c) effective continuous judgement of proper stocking rates throughout the grazing season.--Herb. Abs.

Mahalanobis, P. C.
1933. the use of the method of paired differences for estimating the significance of field trials. Indian Jour. Agr. Sci. 3(2): 349-359.

The use of the method is justified only in special cases as is shown by a discussion of the principles involved. The method assumes no systematic differences or changes in fertility between different plots. Although in adjacent plots soil heterogeneity might be disregarded, it is seldom entirely absent and, therefore, the use of paired differences is seldom justified.--Biol. Abs.

Mason, D. D.
1958. field experiments. (Summary.) Amer. Statis. Assoc. Jour. 53 (282): 585.

Mercer, W. V., and Hall, A. D.
1911. experimental error in field trials. Jour. Agr. Sci. [England] 4: 107-132.

Müller, K. H.
1956. exakte auswertungsverfahren des kontrollierten anbauvergleiches. [an accurate method of carrying out controlled comparative cultivation trials.] Ztschr. f. Landw. Vers. u. Untersuchw., Rostock 2(3): 153-161.

The lay-out and statistical analysis of the method suggested are described.--Herb. Abs.

Okuno, T.
1958. on the design and analysis of field experiments. II. Tokyo Natl. Inst. Agr. Sci. Bul. Ser. A 6: 81-146. [In Japanese with English summary.]

Pan, Chien-Liang.
1935. uniformity trials with rice. Amer. Soc. Agron. Jour. 27: 279-285.

The efficiency index was calculated by dividing the variance of a single-rowed plot by the product of the variance of a multiple-rowed plot times the number of rows included in this plot and expressing the result in percentage, i.e.,

Plot	Variance	Efficiency
1-row	35.049	100.00
2-row	16,066	109.08
3-row	14.084	82.95
4-row	12.286	71.32

Rampton, H. H.
1959. sampling methods for measuring seed yield and seed quality of orchardgrass (dactylis glomerata l.) as determined by uniformity trials. Agron Abs. 1959:87.

Rigney, J. A., Miles, S. R., and Andrews, W. B.
1948. the choice of suitable experimental units and experimental designs. Natl. Joint Com. Fert. Appl. Proc. (1947) 23: 228-234.

The following factors are considered briefly: shape of plots, guard areas, number of replications, locations and seasons, and experimental design.

Rubin, Theodore.
1956. experiments wherein experimental and control groups vary in time and number. Diss. Abs. 16(2): 321.

Shimada, Y.
1958. statistical studies on the design of yield survey and field experiment in natural grassland, 1-2. Tôhoku Univ. Inst. Agr. Res. Sci. Rpt., Ser. D 9(2): 117-136.

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1958. statistical studies on the design of a yield survey and field experiment in natural grassland. 3. Tôhoku Univ. Inst. Agr. Res. Bul. 10(1): 39-54. [In Japanese with English summary.]

Snedecor, George W., and Culbertson, C. C.
1933. an improved design for experiments with groups of animals whose outcome may be estimated. Amer. Soc. Anim. Prod., Proc. (1932) 25: 25-28.

The animals were arrayed according to outcome, then divided into an equal number of rows and columns so that (i) the best animals were in the first row, the next best in the second, etc., and (ii) the best animal in each row was at the left and so on to the poorest at the right. One animal in each row was chosen for each lot with this restriction: no two members of the same column might be in the same lot. R. A. Fisher's Latin square analysis of variance was used. With 100 swine the standard error was 11 percent of the average daily gain.

Summerby, R.
1934. the value of preliminary uniformity trials in increasing the precision of field experiments. Macdonald Col., McGill Univ. Tech. Bul. 15.

Wellman, R. H., Thurston, H. W., Jr., and Whaley, F. R.
1948. a method for correcting for geographic variation in field experiments. Boyce Thompson Inst. Contrib. 15(3): 153-163.

A method for minimizing the geographic variation found in field experiments and examples are given. Geographic variation is defined as any organized variation which affects the data such as soil type, soil profile, moisture or weed population variation. This method makes possible more precise comparisons than are possible on uncorrected data. The method does not impose limitations on number of treatments or replicates and has been found to minimize geographic variation better than existing methods.

Wiener, W. T., and Broadfoot, R.
1925. the effect of fallow borders on the variability of plot yields. Sci. Agr. [Ottawa] 5: 310-312.

The outside drill rows in plots of Mindum wheat, each 8 X 72.6 feet, yielded 26.52 percent more than the 12 central rows, but the effect of the fallow borders did not extend inward beyond the outside rows. --Bot. Abs.

Wilson, Edwin B.
1941. the controlled experiment and the four-fold table. Science 93: 557-560.

Wishart, John.
1938. field experiments of factorial design. Jour. Agr. Sci. [England] 28: 299-306.

In field experiments of the factorial type, the increasing use of individual degrees of freedom necessitates an examination of some dangers lying in their use.

The customary procedure is to compute the mean square for treatments as a whole, which if tested in terms of the error component determines the significance of treatment effects as a group. Frequently, individual degrees of freedom are written out and tested even when treatments as a whole are indicated to be without effect. Such a procedure may lead to unnecessary explanations of significant individual degrees of freedom that may be attributable to chance. The author proposes a X^2 test to determine whether any of the individual single degrees of freedom may be significant.

Yates, F.
1933. the formation of latin squares for use in field experiments. Empire Jour. Expt. Agr. 1(3): 235-244.

The conditions which must be fulfilled in selecting Latin-square arrangements for agricultural field trials, if an unbiased estimate of error is to be obtained, are discussed. Examples of squares up to size 12 X 12 are given, from which experimental arrangements may be derived by simple processes of permutation. All squares up to size 6 X 6 have been enumerated elsewhere, and the totalities of these squares are presented here in compact form.--Auth. sum.

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1933. the principles of orthogonality and confounding in replicated experiments. Jour. Agr. Sci. [England] 23: 108-145.

The term "orthogonal" is used to designate effects which can be directly evaluated without entanglement with others. Except where non-orthogonality is purposefully introduced as in confounding orthogonality should be designed in the experiment. Cases of non-orthogonality introduce complex computation by fitting constants using the least squares method and complicate the interpretation of results because of failure of treatment effects to remain isolated. The principle of confounding, deliberately introducing non-orthogonality into experiments by confounding one of higher order interactions with block differences, is fully discussed. This design is for the purpose of giving greater accuracy on the unconfounded comparisons at the expense of the confounded. By partial confounding accuracy may be gained throughout the experiment.

2. NUMBER OF SAMPLING UNITS AND EFFICIENCY

Borden, R. J.
1943. replication: the safeguard for uncontrolled variation. Hawaii. Planters Rec. 47(3): 135-153.

In field work, sufficient replications must be included to take care of the possible variations that may occur. Variations which may occur in soil, crop composition, plant growth, plant composition, and yields are discussed.--Biol. Abs.

Bormann, F. H.
1953. the statistical efficiency of sample plot size and shape in forest ecology. Ecology 34(3): [474]-487, illus.

Statistical variance was used to determine the most favorable size and shape of plot to sample randomly an oak-hickory forest in the North Carolina Piedmont, as well as to determine the number of plots necessary to obtain a sample of a given precision. It was found that long narrow plots (4 X 140 m. and 10 X 140 m.) crossing any observed contours and soil or vegetational banding are most efficient, especially in the sampling of sporadic species. The size of the sample can be reduced without much loss of precision if segments no longer than the width of the plots are omitted systematically. In this manner a sample covering 7 percent of the total area of the stand gives an estimate of the total basal area that will be within about 10 percent of the mean. The use of random sampling is advocated for several reasons.

Goulden, C. H.
1937. efficiency in field trials of pseudo-factorial and incomplete randomized block methods. Canad. Jour. Res. 15: 231-241.

Chilton, Neal W., and Fertig, John W.
1953. the estimation of sample size in experiments. I. using comparisons of averages. Jour. Dent. Res. 32(4): 530-540.

In order to estimate the size of samples necessary for assertion of statistical significance, the investigator must have information as to what contemplated result is considered important, and possess a certain amount of preliminary data. Illustrations are presented using preliminary data in which comparisons of arithmetic averages are studied, for both independent and correlated samples. By the use of formulas based upon the t-curve and normal curve probability values, and upon the use of a table from the statistical literature, methods are presented for estimating the size of samples necessary for a difference in averages to be found at different significance levels and powers of the test.--N. W. Chilton.

Chilton, Neal W., and Fertig, John W.
1953. the estimation of sample size in experiments. II. using comparisons of proportions. Jour. Dent. Res. 32(5): 606-612.

Formulae are presented for estimating the size of samples necessary for statistical significance to be asserted at different levels of significance and powers of the test, for comparison of a sample proportion with a universe proportion, and for comparison of two sample proportions. A table is presented which will enable the reader to rapidly determine the size of the samples necessary for significance to be asserted at 1 percent level of significance with 99 percent power, or at 5 percent level of significance with 95 percent power. If the reader assumes the smaller true proportion he can read the estimated sample sizes once he knows how much larger the other true proportion is to be. Illustrations from the dental research literature are presented.--N. W. Chilton.

Davis, David E., and Zippin, Calvin.
1954. planning wildlife experiments involving percentages. Jour. Wildlife Mangt. 18(2): 170-178.

Charts are presented which help the planning of experiments by indicating the approximate number of animals required in each sample to establish a difference in percentages as significant at the five percent (probability of a Type 1 error) level. The charts are constructed for two levels of Type 2 error (failure to ascribe significance to a real difference). Discussion of the two types of error, applicability of the respective charts, and several examples are also given.

Holmes, M. C.
1935. sampling analysis and sample size. Franklin Inst. Jour. 219(4): 483-486.

An equation is derived which gives the number of increments per sample (n) required in terms of three factors; the allowed limits of tolerance (x) expressed as a fraction of the mean; the desired degree of assurance that such limits will not be exceeded (y), expressed as a probability; and the inherent variability of the material being sampled (S), measured by the coefficient of variability. The relation is given by the inequality

$$n \geqq \frac{S^2}{X^2}\,[\mathrm{erf}^{-1}(y)]^2,$$

the last member of which may be obtained from error function tables. Normality is assumed in the derivation, but evidence is presented which shows that the equation gives good results even for certain extreme departures from normality.--Biol. Abs.

Knowles, R. P.
1952. the use of lattice designs for testing forage crops. Sci. Agr. [Ottawa] 32(11): 614-617.

Plot arrangement and relative efficiencies are tabulated for 27 lattice tests of perennial forage crops for hay production. Average gains in precision were 51, 44, and 39 percent, respectively, for crested wheatgrass (Agropyron cristatum), bromegrass (Bromus inermis), and alfalfa over comparable randomized block analyses. Good gains in efficiency were noted for tests of 16 strains but not for tests of 9 strains. Six test plots harvested for seed showed an average efficiency gain of 17 percent.

Livermore, J. R., and Neely, Winston.
1933. the determination of the number of samples necessary to measure differences with varying degrees of precision. Amer. Soc. Agron. Jour. 25(9): 573-577.

Tables are presented by means of which, if the probable error of a single observation is known, one may predict with a reasonable degree of accuracy the number of plots or other units necessary to measure a known difference with any desired degree of precision. Examples illustrating certain uses of the tables are presented in detail. The use of these tables is predicted on the assumption that the deviations in the particular experiment conform to the normal curve of error.--Biol. Abs.

Ma, R. H., and Harrington, J. B.
1948. the standard errors of different designs of field experiments at the university of saskatchewan. Sci. Agr. [Ottawa] 28(10): 461-474.

During the 22-year period, 1925 to 1946, 523 field plot experiments of various types of design were conducted. The standard errors per plot in percent were obtained for the different experiments and a study made to ascertain the average value of the standard deviation for each type of design used for the different crops; the relative efficiency of these designs for field testing; and the probable number of replicates required in the planning of future experiments. The results offer an overwhelming case in favor of the use of lattice designs under conditions such as obtained in the tests considered. Latin squares proved efficient but the limitation of this design to very few varieties made it unsatisfactory for testing large numbers of varieties. The randomized blocks were definitely inferior to the lattice designs. The semi-Latin squares not only averaged high in percentage standard error per plot but also had the added disadvantage of the bias in the estimation of error. The lattices were superior to the split-plot latin squares and to the split-plot randomized blocks. The split plot type of design proved to be the closest approach to lattices in one respect, viz., varietal

comparisons within groups. However, comparisons between groups which constitute the majority of comparisons between pairs of varieties were low in precision.--J. B. Harrington.

Pope, O. A.
1936. efficiency of single and double restrictions in randomized field trials with cotton when treated by the analysis of variance. Ark. Agr. Expt. Sta. Bul. 326.

The efficiency of restricted arrangements varied between tests of the same size of different locations, as well as between tests of different sizes. All sizes and arrangements used were capable of significantly increasing the accuracy of interpretation. In general, greater efficiency of restricted arrangements was found in tests located on permanent experimental blocks arranged in an orderly manner. Decreases in efficiency were roughly proportional, inversely, to the amount of care used in selecting the experimental area. Even with the most careful selection of the experimental area, a sufficient increase in accuracy usually results from restricted arrangements to warrant the general use of the method in field experiments.

Shimada, Y.
1959. statistical studies on the design of yield survey and field experiment in natural grassland. 3. estimation of yield especially with reference to size and shape, and replication of field experimental plot in natural Zoysia grassland. Tôhoku Univ. Inst. Agr. Res. Sci. Rpt., Ser. D. 10(2): 87-107.

Swineford, Frances.
1946. graphical and tabular aids for determining sample size when planning experiments which involve comparisons of percentages. Psychometrika 11(1): 43-49.

Charts are presented which eliminate any computation where the two groups involved are to be equal. A table is included for the case where one group will be one to three times the size of the other. The charts are also useful for determining whether or not obtained differences are statistically significant at the 5 percent or the 1 percent level.--Frances Swineford.

Torrie, J. H., Shands, H. L., Leith, B. D.
1943. efficiency studies of types of design with small grain yield trials. Amer. Soc. Agron. Jour. 35(8): 645-661, illus.

The data consisted of the grain yields from the wheat, oats, and barley rod-row and 1/60-acre plot experiments conducted by the Department of Agronomy at the University Hill Farms, Madison, Wis.,

during the period 1937-1942. Data obtained from the rod-row nurseries at the Hancock and Marshfield branch experiment stations are also included for the period 1938-1941. The precision of the lattice design, with and without recovery of inter-block information, as compared to the randomized complete block was determined for 22 small grain trials. The average of all tests gave an increase of 9 percent in precision with recovery of inter-block information and a loss of 8 percent when inter-block information was ignored. Four quadrats harvested from 1/60- or 1/80-acre field plots provided, for the most part, reliable estimates of the yield of the entire plot. The precision of the quadrats as measured by the coefficient of variability is essentially the same as that of the field plots. A good agreement was found for most of the varieties tested when grain yields from rod-row plots were compared with those from field plots and quadrats. Calculations based on the 19 field-plot trials showed that increasing the number of replications would be more effective than increasing the number of quadrats per plot as a means of increasing precision. The average precision factors calculated for different numbers of quadrats and replicates were essentially the same for the different cereals, especially for oats, spring wheat, and winter wheat.--Biol. Abs.

Yates, F., and Zacopanay, I.
1935. the estimation of the efficiency of sampling, with special reference to sampling for yield in cereal experiments. Jour. Agr. Sci. [England] 25: 545-578.

A preliminary discussion of the interpretation of the analysis of variance as applied to sampling results is given, and an expression is found for the loss of information arising out of sampling applicable to all types of sampling carried out on replicated experiments. The method of determining the optimal percentage of sampling is described. Gain due to subdivision of the plots for sampling is shown to be advantageous.

Ansari, M. A. A., and Sant, G. K.
1943. a study of soil heterogeneity in relation to size and shape of plots in wheat field at raya (muttra district). Indian Jour. Agr. Sci. 13(6): 652-658, illus.

Standard errors indicate that a plot of 270-360 sq. ft. is optimal for wheat variety trials. Long plots had no advantage over broad plots of the same area. The Papadakis method of adjustment for fertility indices increased the accuracy of measurement of differences.--C. H. Arndt.

Archbald, D.
1950. the effect of quadrat size and quadrat method on apparent plant dispersion. (Abstract) Ecol. Soc. Amer. Bul. 31: 52.

Bonazzi, A.
1933. errors in field experimentation with ratoon cane. Asoc. de Téc. Azucareros Cuba, Proc. 7: 32-40.

The practical value of experimental results depends on two fundamental factors: (1) the reliability of the absolute value of the mean of an appropriate series of repetitions, and, (2) the variability of the individual values obtained in this series, i.e., the form of frequency curve which represents their values, expressed in terms of standard deviation $\pm \sigma$ or of probable error $\pm$ e. It is clear that the mean of 50 measurements made with a measuring rod which, due to an error in manufacture, measures only 90 cm. instead of 100, will be 1.111 times greater than the true distance existing between two points, even though the individual deviation from the mean value of a series of measurements, made with this same rod, be very small. With this concept in mind, and as a final conclusion to the present study, it may be stated that: due to obvious economic limitations that do not permit numerous replications of large plots, experimentation with ratoons of sugar cane may be made with plots of 600 sq. m. (combination a X 6 in a row) since this size and shape unites a high index of probability to a minimum systematic error realizable with a limited number of replications.--Auth. sum.

Bose, R. D.
1935. some soil-heterogeneity trials at pusa and the size and shape of experimental plots. Indian Jour. Agr. Sci. (5): 579-608.

Christidis, Basil G.
1931. the importance of the shape of plots in field experiments. Jour. Agr. Sci. [England] 21: 14-37.

1. In agricultural experiments it seems that significant results cannot be secured by only using appropriate statistical methods; uniformity amongst the individual plots is more essential than anything else. 2. Some theoretical considerations suggest that the shape of the plots constitutes an important means of controlling soil heterogeneity. In accordance with these: (a) in no case can square plots be more uniform than long and narrow ones; (b) the smaller the value w/l the more uniform the experimental plots, and (c) since uniformity depends (apart from w/l) on the value of the angle a, in some exceptional cases (soil fertility varying gradually and evenly, and angle a approaching 90°) the advantage of the long plots may be less than would be anticipated. This, however, is most unlikely on account of the complexity of the variation in soil conditions and the possibility of easily avoiding such a critical value of the angle a. 3. In order to test the validity of the assumption made regarding the effect of the shape of the plots, the numerical data of several uniformity trials have been considered. A close agreement was found between expectation and actual results, in the great majority of cases the evidence being remarkably significant in favor of the long plots. In only 3 cases were the results inconclusive, this apparently being accounted for by the way in which the original plots were formed, causing an inequality in area amongst them. 4. In the light of these investigations, in order to reduce the effect of soil heterogeneity, the plots used should be as long and narrow as possible. This, of course, within the limits set by different practical considerations, amongst which convenience, competition (when acting), and the accurate measurement of the width appear to be the most important.--Auth. sum.

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1939. variability of plots of various shapes as affected by plot orientation. Empire Jour. Expt. Agr. 7(28): 330-342, illus.

Long and narrow plots were generally more effective than squares in controlling soil heterogeneity. To find out if this is true irrespective of the orientation of the plot an experiment was made in which 5 shapes were compared in 4 different orientations. In no case were long and narrow plots more variable then squares, the difference in their variability depending entirely on the ratio w/l (width over length) of the respective plots. Loesell's data considered in this respect provided additional evidence in favor of long plots.--Biol. Abs.

Clapham, A. R.
1932. the form of the observational unit in quantitative ecology. Jour. Ecol. [London] 20(1): 192-197.

From subdividing a square 4 meters on a side into 256 squares 1/4 meter on a side, in a closely grazed turf, author concludes that the variance (standard deviation squared) among square meter quadrats is about twice that among (1/4 X 16) strips of the same size. He suggests that the meter quadrat be replaced by a strip 4 meters by 1/4 meter on the side.

Dorph-Petersen, K.
1949. parcelfordeling i markforsøg. [plot arrangement in field experiments.] Tidsskr. for Planteavl [Copenhagen] 52(1): 11-175.

Investigations on the effect of plot arrangement on experimental error, involving the use of uniformity trials, mainly of Danish origin, showed that in a Latin square field experiment, Fisher's restriction greatly reduces the experimental error. The different plot arrangements in field experiments of that type give somewhat different values for "F" but the variation in "F" is not greater than may be due to coincidence. The error of a difference between two treatments indicates that in many experiments the yields of different treatments are not independent of each other. The difference in yield between adjacent plots treated differently is smaller than between nonadjacent ones. Among the types of arrangements used in experiments with long, narrow plots in a single range investigated in this paper the type with the same arrangement of plots repeated in blocks showed the smallest error. A few types of large experiments suited to the Latin square method were examined.

Down, E. E.
1942. plot technic studies with small grains. Amer. Soc. Agron. Jour. 34(5): 472-481.

Studies were made with fall-sown wheat and spring-sown barley for 5 seasons to determine the width of plot necessary to overcome the influence of competition between contiguous nursery plots. Ten replications of competitive plots were alternated for 2 rates of seeding and for 2 varieties for both grains, using plots 1, 3, 5 or 7 rows wide. The effect of competition did not extend beyond the outside border rows of a plot to a statistically measurable amount; a 5-row plot for wheat and a 3-row plot for barley with the border rows discarded at harvest are satisfactory for nursery investigations. A minimum of 3 replications for wheat and 7 for barley was necessary (for the plot widths mentioned) to reduce the standard error of the mean to 5 percent of the mean.

Geidel, H.
1958. zur variabilität der einzelpflance. [the variability of the individual plant.] Ztschr. f. Acker- u. Pflanzenbau [Berlin] 106(1): 49-57.

The magnitude of the variability of plant attributes is studied statistically and used for determining the optimum size of sampling unit of a crop plant.--Herb. Abs.

Hanson, Herbert C.
1934. a comparison of methods of botanical analysis of the native prairie in western north dakota. Jour. Agr. Res. 49(9): 815-842.

The methods tested were area-list, count-list, weight-list, frequency-abundance, and the point method. A study was also made of various sizes and shapes of sample areas and plots. The use of sample areas located in plots was recommended in place of sample areas not in plots. The minimum desirable size was found to be 2 X 3 rods containing 24 sample areas, each sample area being 0.1 m. square. It is concluded that reliable quantitative results may be secured when listing is done on sample areas arranged in plots, both in sufficient numbers for systematic treatment. Valuable supplementary information will be furnished by use of the point and frequency-abundance methods since with them it is possible to cover large areas quickly. For extensive studies and where time and assistance are limited, the point and frequency-abundance methods, supplemented by permanent quadrats, are recommended.--Biol. Abs.

Hanson, H. C., and Love, L. D.
1930. size of list quadrat for use in determining effects of different systems of grazing upon agropyron smithii mixed prairie. Jour. Agr. Res. 41: 549-560, illus.

Hatheway, W. H., and Williams, E. J.
1958. efficient estimation of the relationship between plot size and the variability of crop yields. Biometrics 14(2): 207-222.

An improved method of estimating the coefficient in Fairfield Smith's empirical relationship between plot size and variability is described and illustrated on data from an agricultural field trial. The coefficient is determined from a weighted regression in which the weighting takes into account the correlations and unequal variances of the variance estimates.--Biol. Abs.

Holloway, J. T. and Wendelken, W. J.
1957. some unusual problems in sample plot design. New Zeal. Jour. Forestry 7(4): 77-83, illus.

Sample plots are being established along selected sampling lines throughout the high-mountain protection forests of New Zealand, to measure changes in the vegetation, particularly those consequent on the presence of introduced animals and affecting the soil-conservation and water-regulation values of the forests. The present

condition of the forests must be recorded as thoroughly and accurately as possible, but physical factors, examples of which are given, impose severe limitations on plot design. The design adopted, a 1/10-acre cruciform belt transect with internal circular milacre sub-plots, is a compromise. Items recorded on each plot are listed briefly.--Biol. Abs.

Hudson, H. G.
1939. population studies with wheat. Jour. Agr. Sci. [England] 29(1): 76-109, illus.

The design and field technique of 2 large-scale experiments, laid down to investigate the problems of sampling and "propinquity" are described in detail. These experiments were designed so that plant number, stem number, ear number, straw weight and grain weight for 7200 lengths of 6 inches of drill row, together with the position of each observation, might be obtained. The lowest sampling error, expressed as a percentage of the mean, is obtained by using the smallest sampling unit but the large number of sampling units of this size that would have to be taken make it impracticable. Optimum sampling unit consists of 6 inches of drill row taken as 3 inches in 2 adjacent rows. As size of sampling unit is more important than shape in determining its accuracy, little was lost by using sampling units of 18 inches in 5 adjacent rows. The observations of grain weight require a sample about twice as large as that required for other observations. The larger the plot the lower the sampling percentage necessary to obtain any given accuracy. Subdividing plot and taking equal numbers of sampling units from each subdivision greatly increases the accuracy of sampling. The actual percentages necessary to insure accuracy under various plot sizes and degrees of subdivision are given.

Hutchinson, J. B., and Panse, V. G.
1935. studies in the technique of field experiments. I. size, shape and arrangement of plots in cotton trials. Indian Jour. Agr. Sci. 5: 523-538.

Ilvessalo, Vrjö.
1921. vegetationsstatistische untersuchungen über die waldtypen. [statistical investigations on the vegetation of forest types.] Acta Forest. Fenn. [Helsinki] 20: 1-73, illus.

The investigations in question pertaining to forest types were made in the southern half of Finland in even-aged, regular, and clean forest stands. They show that the number of higher plant species to a sample plot is different in different forest types (presupposing the stand to be of the same age and equally dense throughout); and from the poorest to the best types it rises distinctly and regularly. It is shown, principally by graphs and with the assistance of correlation calculations and mean average values, that in

studying the number of plant species in any chosen plant-community (at least in forests) a few plots will not suffice, even though they be large (1/8-1/4 ha.). The richer the community is in species and the more luxuriant its growth the larger the number of plots necessary for its analysis. Satisfactory results are not obtainable from small plots of a few square meters. Elongated sample plots have proved more satisfactory than square ones, but for heterogeneous types, rich in species, broad strips are most satisfactory. --L. Ilvessalo (translated), Bot. Abs.

Immer, F. R., and Raleigh, S. M.
1933. further studies of size and shape of plot in relation to field experiments with sugar beets. Jour. Agr. Res. 47(8): 591-598, illus.

The standard errors in percentage of the mean decreased with increasing size of the plots. When the entire plot was harvested, the efficiency in use of the land decreased as plot size increased. When a single border row was removed on each side of the plot, the 4-row width was decidedly the most efficient. The regression of yield of all plants in a plot on total number of beets was essentially linear. Stands of the various plots varied from 50 to 100 percent.

Johnson, Floyd A., and Hixon, Homer J.
1952. the most efficient size and shape of plot to use for cruising in old-growth douglas-fir timber. Jour. Forestry 50(1): 17-20.

A 66 X 198-ft. rectangular plot was found to be the most efficient of the 12 kinds of plot that were tested.

Justesen, S. H.
1932. the influence of size and shape of plots on the precision of field experiments with potatoes. Jour. Agr. Sci. [England] 22: 366-372.

A uniformity trial with potatoes was used for investigating the effect of size and shape of plots on the precision of field experiments. Up to a certain limit the standard deviation in percent of the mean decreases when the size of plots is increased; further increase of plot size increases the errors as a lesser part of the soil variation can be removed. When the area to be used is fixed, smaller plots are more efficient than larger, owing to the greater number of replications in the formercase. Long and narrow plots are more efficient than shorter and wider ones of the same size. In field experiments with potatoes fairly large plots should be used; at least 2 rows wide and preferably long and narrow strips.

Kalamkar, R. J.
1932. experimental error and the field-plot technique with potatoes. Jour. Agr. Sci. 22: 373-383.

An investigation using data from a uniformity trial with potatoes confirms the findings of Justesen that the standard error in percent of the mean decreased slightly with the increase in plot width up to a certain point. Increased size of the plot resulted in a decrease in efficiency which points to increased replication with plots of smaller size. Long narrow plots are more efficient than shorter wide plots.

Khanna, K. L., Nigam, L. N., and Bandyopadhyay, K. S.
1950. studies in sampling technique. II. estimation of pyrilla incidence in sugarcane. Indian Acad. Sci. Proc. Sect. B. 31(1): 34-45, illus.

Two plots, each measuring 60 X 60 ft., infested with Pyrilla were completely enumerated to find the minimum sample size for the estimation of incidence at a desired level of precision. Of the two plots, plot I had a denser crop and slightly more infestation than plot II, but the variation of incidence in plot II has been of a slightly higher order than in plot I. Four characters have been simultaneously used to define incidence and the sample sizes have been worked out in terms of the percentages of the total 3 ft. units available in the plots. The sample sizes are such as would furnish the estimates within an error of 7 percent.--Auth. sum.

Koch, E. J., and Rigney, J. A.
1951. a method of estimating optimum plot size from experimental data. Agron. Jour. 43(1): 17-21.

Leonhard, H.
1932. uber die genauigkeit und zuverlässigkeit der quantitativ-botanischen untersuchung bei wiesenversuchen. [on the exactness and reliability of the quantitative botanical analysis in grassland trials.] Arch. f. Pflanzenbau [Berlin] 8: 650-682.

(1) As the size of the trial plots and the number of samples were increased, the number of species present in the samples also increased, at first considerably, then more slightly. (2) The accuracy of the results of sample taking on plots with heterogeneous stands was numerically very slight, and it was naturally still less the more heterogeneous the stand. (3) Shape of the trial plot. Elongated, narrow plots generally gave more accurate results than quadrat-shaped plots of equal or even larger area. (4) Size of the plots. As the size of the plots increased error became at first less, but only up to a certain point, after which error began to increase again, because as the area was extended so did the difference in plant stand tend to increase. (5) Even if samples from

definitely limited areas lead to more accurate results than single or average samples, from the practical point of view the two latter are to be preferred. (6) Number of trial plots. With the increase in the number of trial plots accuracy increased at first considerably, later to a less extent. Reduction of error by increasing the number of samples taken was very slow. The increased effort involved is by no means in scientifically and economically justifiable ratio to the result. For this reason a relatively high degree of inaccuracy must often be allowed in the case of comparatively small proportions of a species. (7) In ascertaining the proportion of individual species, one has to reckon with comparatively large errors. These are the less, the more uniform and large the proportion of the particular species in the sward. (8) The reliability values showed in general the same tendency as the accuracy values. In spite of the greater unreliability of the results obtained from "single samples" and "average samples," as compared with samples from limited, definite sample areas, the probability is that the former are more "just." [Translation of author's summary.]

McClelland, C. K.
1926. some determinations of plot variability. Amer. Soc. Agron. Jour. 18: 819.

MacDonald, D., Fielding, W. L., and Ruston, D. F.
1939. experimental methods with cotton. I. the design of plots for variety trials. Jour. Agr. Sci. [England] 29: 35-47.

Mahalanobis, P. C.
1946. use of small-size plots in sample surveys for crop yields. Nature [London] 158: 798-799.

A discussion is presented of the various ways in which sample size and shape of sample plot may prejudice accurate estimations of yields.

Ovesnov, A. M.
1937. on the size of the sample square in the study of phytocoenoses on continental grasslands. Učen. Zap. Perm. Univ. 2(4): 137-143. [English summary, 142-143.]

Of the eight sizes tested on nineteen phytocoenoses the round plot of 50 sq. m. proved to be most significant; it registered 85 percent of species composing a phytocoenosis, including all the typical species. With a larger size of plot the number of species increased, but mainly at the expense of less important species. In comparative studies of phytocoenoses the size of the sample plots must be uniform. --Herb. Abs.

Panse, V. G.
1946. plot size in yield surveys on cotton. Current Sci. [India] 15(8): 218-219.

Small plots, 1/200 acre and less, give biased estimates of the yield of the whole field.

Pechanec, Joseph F., and Stewart, George.
1940. sagebrush-grass range sampling studies: size and structure of sampling unit. Amer. Soc. Agron. Jour. 32(9): 669-682.

Herbage yield data of arrowleaf balsamroot (Balsamorhiza sagittata) and tapertip hawksbeard (Crepis acuminata), collected on 640 5 X 5 ft. plots located in the sagebrush-grass vegetation type at the U.S. Sheep Expt. Station, Dubois, Idaho, were used in testing the efficiency of various sampling-unit sizes and shapes and in exploring the influence of subdivision of sampling upon accuracy of the sample. Principles of sampling previously evolved in agronomic research held for native vegetation, viz., smaller sampling units tended to be more efficient per unit area than larger units, and long narrow units more efficient than square or round units. In selection of a sampling unit for use an effective balance must be established between statistical efficiency and such practical factors as time involved and accuracy of observation. By trial a complex type unit, designated as the line-plot, and subdivision of the area in sampling were found to hold much promise for use with native vegetation. Subdivided random sampling, using line-plot units whose subunits were approximately 50 sq. ft. in area, was recommended for trial in sampling similar sagebrush-grass range areas.--J. F. Pechanec.

Pielou, E. C.
1957. the effect of quadrat size on the estimation of the parameters of neyman's and thomas's distributions. Jour. Ecol. [London] 45(1): 31-47, illus.

Models of Neyman's type A and Thomas's distributions, with the clusters occupying appreciable areas, were constructed and sampled with quadrats of various sizes. Results show that these distributions are indistinguishable by quadrat sampling and that the size of quadrat used greatly affects the form of observed frequency distributions obtained. In all cases the derived statistic which should give an estimate of number of points per cluster was too low. The highest and most nearly correct estimates of this parameter were obtained by sampling a population with quadrats of several sizes and calculating the regression of log percentage absence on density. The constant term in the regression equation gives some idea of the degree of diffuseness of the clusters constituting the population.

Robinson, H. F., Rigney, J. A., and Harvey, P. H.
1948. investigations in peanut plot technique. N. C. Agr. Expt. Sta. Tech. Bul. 86, 19 pp.

Two years' uniformity data were used to estimate the most efficient size and shape of plot and to evaluate certain incomplete block designs. The basic data were taken on 12½-ft. single-row units. The coefficient of variability decreased with increasing plot size and the long narrow plots were more effective than the short wide ones. Increasing the number of plots per block from 6 to 16 did not increase the error perceptibly. The technique suggested by H. Fairfield Smith for determining optimum plot size was also used. The expression for the variance of a treatment mean (on a per-unit basis), $V_{(x)} = \frac{V}{rx^b}$, was transformed to a logarithm scale to give the regression form $\log V_{(x)} = \log V - \log r - b \log x$. The coefficient b was estimated from the data to average 0.57 for the two years and is used as an indication of soil heterogeneity. A cost function was set up and minimized to give the optimum plot size for any degree of soil heterogeneity and any distribution of cost. When the proportion of cost that is related to plot size is low, small plots are most efficient regardless of soil uniformity. As this cost increases, larger plots become the most economical, especially on less uniform soils. A balanced lattice gave very little gain in precision with 16 entries and small plots. The gains tended to increase as the number of entries and plot size increased. Triple lattices were only slightly less efficient than the balanced lattice but simple lattices lost up to 15 percent of the gains when the balanced lattice had a relative precision of 200. Lattice squares were slightly more efficient than balanced lattices since columns accounted for some of the residual error.--H. F. Robinson.

Schmitt, L., and Brauer, A.
1958. untersuchungen über die gegenseitigen randbeeinflussungen verschieden gedüngter teilstücke bei langjährigen feld- und wiesendüngungsversuchen. [reciprocal edge effects between differently manured plots in long-term arable and grassland experiments.] Landw. Forsch. [Germany] 11(1): 10-22, illus. [English and French summaries.]

Edge effects were investigated in plots of arable land and grassland which had undergone manurial trials for 54 and 40 years, respectively. P_2O_5, K_2O, and pH were determined. As a consequence of soil cultivation mutual edge effects occurred in the arable experiment, often extending into the plots by 75 cm. or more. Only slight effects, confined to the utmost edge of the plots, were found on the grassland plots which were separated by shallow furrows 10 to 12 cm. wide. Consequently, plots in arable long-term experiments should be large enough to include discard strips 1 m. wide at the edges of the treated area. For grassland experiments no such guard strips are needed, provided that the plots are separated clearly by furrows, and herbage samples are not taken from their very extreme edges. --Herb Abs.

Shimada, Y.
1958. statistical studies on the design of a yield survey and field experiments on natural grassland. pt. 1. estimation of yield, especially with reference to size, shape and replication of field experimental plots in natural miscanthus grassland. Tôhoku Univ. Sci. Rpts. Res. Insts. Ser. D 9(2): 117-130, illus.

The area studied was a natural grassland in Miyagi Prefecture in which Miscanthus sinensis 180 cm. high was dominant and belonged to the frequency class 5. The object was to study production of M. sinensis. A rectangular area 16 m. X 64 m. was divided into 1024 square-metre quadrats. Production (fresh weight) was expressed in 5 classes each of 1000 g. per sq. m. and the results were charted. By combining sq. m. quadrats, blocks of different shapes and sizes were formed, from 1 X 1, 1 X 2, etc. to 8 X 8 sq. m., their number ranging from 128 for 1 X 1, sq. m. to 2 for 8 X 8 sq. m. The larger the sampling unit, the smaller was the coefficient of variation, but shape of block had no effect. On this land, which had a slope of 15.8°, stratified sampling with horizontal strata gave results which were 10-50 percent more accurate than purely random sampling. For measuring production of Miscanthus grasslands, plots of 8 X 8 sq. m. with 8 replications are recommended.--Herb. Abs.

Siao, Fu.
1935. uniformity trials with cotton. Amer. Soc. Agron. Jour. 27: 974-979.

Increase in size of plot reduces experimental error, but larger plots lower in efficiency than smaller. Increased replication much more efficient than increased plot size. Increase in size of plot in direction of least association is most efficient. Because of high seasonal variation no definite number of replication could be recommended. Experimental error larger in unfavorable than in a favorable season.

Smith, H. Fairfield.
1938. an empirical law describing heterogeneity in the yields of agricultural crops. Jour. Agr. Sci. [England] 28: 1-23.

Using data from a blank experiment with wheat, it was found that the regression of the logarithms of the variances for plots of different areas on the logarithms of their areas was approximately linear. A graphical review of variances indicates that most uniformity trials conform to such law. It is shown that the above law can be generalized (so as to apply to any size of field) by applying a certain adjustment to the regression coefficient b' to give a modified coefficient b applicable to an "infinite" field. From this generalized relationship there has been deduced an expression to indicate average relative efficiencies to be expected for randomized block experiments with varying numbers of plots per block in a field

for which the coefficient b is known. A formula which may be used to extimate the most efficient size of plot for any given experiment has also been deduced. The cost of using plots of other than the most efficient size is indicated graphically.

Sukhatme, P. V.
1947. use of small-size plots in yield surveys. Nature [London] 160(4068): 542.

The author reaffirms, contra Mahalanobis, the advantage of large plots (1/80 acre) for estimating yield. The largest factor of bias is the choice of including or excluding border plants; random selection of plot can be adequately controlled.--R. Walker.

Summarby, R.
1925. a study of sizes of plats, numbers of replications and the frequency and methods of using check plats, in relation to accuracy in field experiments. Amer. Soc. Agron. Jour. 17: 140-150.

Small plats were more accurate than large plats. There is a steady and rapid increase in accuracy as the number of replications is increased. There was no consistency as regards the effect of more or less frequent checks no matter what system of checking was used.

Tsai, H., and Chow, C. Y.
1943. studies on plot technique in wheat. Chinese Jour. Sci. Agr. [Chungking] 1(2): 93-118. [In Chinese with English summary]

Analysis of the experimental results gave the following conclusions: For any given plot size, long, narrow strips give greater precision than short, wide ones; replication under 6 may decrease the experimental errors as much as expected; with systematic arrangements the deviations from mathematical expectation are greater than those derived from random arrangement but this method of interpreting results will not lead to a serious error and facilitates the mechanical operation of taking records; the pseudofactorial and incomplete randomized blocks methods are more efficient for testing a large number of vars.--F. H. Wang.

Wiebe, Gustav A.
1935. variation and correlation in grain yield among 1,500 wheat nursery plots. Jour. Agr. Res. 50(4): 331-357.

Federation C.I. No. 4734 was grown in a uniformity trial. The ultimate plots were rows 1 ft. apart and 15 ft. long. Total variation tended to increase when more and more land was added, provided the size and shape of the ultimate unit remained the same. When, however,

more and more land was added by increasing the size of the ultimate plot (the number remaining the same) total variation tended to decrease. When the entire experimental area was used in each study of variation with increasing row lengths, the variation decreased and was a function of n, the number of ultimate plots combined, and r, their intraclass correlation. The correlation of the yields of adjacent rows was high and decreased in a nearly linear relation until the rows were 48 ft. apart; beyond this distance statistically significant correlations could not be established. The intraclass correlation coefficient, calculated according to a formula of Harris, increased as the size of the combination plot, compounded by contiguous association, decreased, provided the shape remained constant. When the size of the combination plot remained the same, the coefficient increased as the shape of plot approached a square. The variation of the ultimate plots (rows) within combination plots, compounded by contiguous association, decreased when the shape was constant but the size decreased, and also when the size was constant, but the shape approached a square. The variation within combination plots, compounded by noncontiguous association, approached the total variation. The nearness of approach depends on the intraclass correlation. The variation between combination plots, compounded by contiguous association, increased when their shape was constant but their size decreased, and also when their size was constant but their shape approached a square. The variation between combination plots, compounded by non-contiguous association, decreased as the number of ultimate plots grouped became larger, the reduction being nearly proportional to $\sqrt{n}$, the number of plots grouped. A greater reduction in variation between combination plots was secured when an equal number of replicates were distributed noncontiguously than when they were distributed contiguously. The actual and theoretical curves for the variation agree exactly when the latter is calculated as a function of both n and r. Less bias was secured in the estimate of the experimental error when the replicates were distributed completely at random as contrasted with systematic distributions. When the varieties of each replication were arranged according to the principle of maximum contiguity the experimental error was reduced. Two systems, involving the principle of maximum contiguity, are suggested as plot arrangements for nursery practice. In one system the varieties or hybrids to be tested are divided into groups of 5 (1 of the group is always a check or standard variety) and replicated the desired number of times. The arrangement within the group is random for the several replications. In the other system they are arranged in the same sequence in the replications with every fifth variety a check. The experimental error is calculated by analysis of variance for each group of 5 when their number is not too large. Where there are many groups, the average error from several groups of 5 may be applied theoughout all the groups of 5. When the varieties or hybrids are planted in sequence as in the second system, the error may be used as a "moving error" and is applied to any contiguous group of 5 varieties or hybrids. The "moving error" permits any variety or hybrid to be compared with the check or standard variety on either side.--Biol. Abs.

Wiener, W. T., and Broadfoot, R.
1925. the amount of variability which may be expected to occur in a determination of comparative yields in small grain. Sci. Agr. [Ottawa] 5: 305-309.

The yields of 94 1/100-acre plots of Mindum wheat were compared when taken singly and when grouped to form plots of 1/50-, 1/25-, and 1/10-acre each. The conclusion is reached that 1/100-acre plots replicated 3 or 4 times give a higher degree of precision than larger plots with fewer replications.--Bot. Abs.

ABBREVIATIONS FOR TITLES OF PUBLICATIONS

Acta Agr. Fenn. [Helsinki]	Suomen Maataloustieteellinen Seuran. Julkaisuja. Acta Agralia Fennica. Helsinki.
Acta Agr. Suecana [Sweden]	Acta agriculturae suecana. Sweden.
Acta Bot. Neerlandica	Acta botanica neerlandica. Amsterdam, Netherlands.
Acta Forest. Fenn. [Helsinki]	Acta Forestalia Fennica. Suomen Metsätieteellinen Seura. Finska Forstsamfundet. Arbeiten der Forstwissenschaftlichen Gesellschaft in Finland. Helsinki.
Adv. Agron.	Advances in agronomy. New York, N.Y.
Agr. Assoc. China Jour.	Agricultural association of China Journal. Tai-pei, Formosa.
Agr. and Livestock in India	Agriculture and Livestock in India. Delhi.
Agr. Jour. Brit. Guiana	Agricultural Journal of British Guiana. Department of Agriculture. Georgetown.
Agr. Jour. India	Agricultural Journal of India. Calcutta.
Agr. Prog. [Cambridge]	Agricultural Progress. Agricultural Education Association. Cambridge, England.
Agr. Trop. [Colombia]	Agricultura Tropical. Bogotá, Colombia.
Agrártudomány [Budapest]	Agrártudomány. Budapest, Hungary.
Agricultura [Madrid]	Agricultura; Revista Agropecuaria. Madrid.
Agron. Abs.	Agronomy Abstracts. American Society of Agronomy. Madison, Wis.
Agron. Jour.	Agronomy Journal. American Society of Agronomy. Madison, Wis.
Amer. Cattle Prod.	American Cattle Producer. Denver, Colo.
Amer. Geophys. Union Trans.	American Geophysical Union Transactions. Washington, D.C.
Amer. Jour. Bot.	American Journal of Botany. East Lansing, Mich.
Amer. Midland Nat.	American Midland Naturalist. Notre Dame, Ind.
Amer. Potato Jour.	American Potato Journal. Somerville, N. J.
Amer. Soc. Agron. Jour.	American Society of Agronomy, Journal. Geneva, N. Y.
Amer. Soc. Anim. Prod. Proc.	American Society of Animal Production. Record of Proceedings of Annual Meeting.
Amer. Soc. Hort. Sci. Proc.	American Society for Horticultural Science. Proceedings. College Park, Md.
Amer. Statis. Assoc. Jour.	American Statistical Association. Washington, D.C.
An. de Edafología y Fisiol. Veg. [Madrid]	Anales de Edafología y Fisiología Vegetal. Spain.
Ann. Agron. [Paris]	Annales Agronomiques. Paris.
Ann. Appl. Biol. [London]	Annals of Applied Biology. London.
Ann. Bot. [London]	Annals of Botany. London.
Ann. della Sper. Agr. [Rome]	Annali della Sperimentazione Agraria. Rome.
Ann. Eugenics [Cambridge]	Annals of Eugenics. Cambridge, England.
Ann. Math. Statis.	Annals of Mathematical Statistics. Ann Arbor, Mich.

Arch. f. Forstw. [Berlin]	Archiv für Forstwesen. Berlin, Germany.
Arch. f. Met., Geophys. u. Bioklimatol. Ser. B. [Austria]	Archiv für Meteorologie, Geophysik und Bioklimatologie. Ser. B. Austria.
Arch. f. Pflanzenbau [Berlin]	Archiv für Planzenbau. Berlin and Leipzig.
Ark. Agr. Expt. Sta. Bul.	Arkansas University. College of Agriculture. Agricultural Experiment Station. Fayetteville, Ark. Bulletin.
Asiatic Soc. Bengal, Jour. and Proc.	Asiatic Society of Bengal. Journal and proceedings. Calcutta.
Asoc. de Téc. Azucareros Cuba, Proc.	Asociación de Técnicos Azucareros de Cuba. Habana.
Austral. C.S.I.R.O. Wildlife Res.	Australia Commonwealth Scientific and Industrial Research Organization. Wildlife and Research.
Austral. Council Sci. and Indus. Res., Bul. (or Jour.)	Australia. Council for Scientific and Industrial Research. Melbourne.
Austral. Inst. Agr. Sci. Jour.	Australian Institute of Agricultural Science Journal. Sydney, N. S. Wales.
Austral. Jour. Agr. Res.	Australian Journal of Agricultural Research. Melbourne.
Austral. Jour. Appl. Sci.	Australian Journal of Applied Science. Melbourne.
Austral. Jour. Bot.	Australian Journal of Botany. Melbourne.
Austral. Jour. Sci.	Australian Journal of Science. Sydney.
Austral. Jour. Sci. Res. Ser. B.	Australian Journal of Scientific Research. Series B: Biological Science.
Barcelona R. Acad. de Cién. y Artes, Mem.	Reale Academia de Ciéncias y Artes de Barcelona. Barcelona, Spain.
Biol. Abs.	Biological Abstracts. Baltimore.
Biol. Sci. [Tokyo]	Biological Science. Tokyo, Japan.
Biometrics	Biometrics. Raleigh, N. C.
Biometrika [London]	Biometrika; a Journal for the Statistical Study of Biological Problems. London.
Bot. Abs.	Botanical Abstracts. Baltimore.
Bot. Gaz.	Botanical Gazette. Chicago.
Bot. Mag. [Tokyo]	Botanical Magazine. Tokyo.
Bot. Notiser [Sweden]	Botaniska Notiser. Lund, Sweden.
Bot. Rev.	Botanical Review. Lancaster, Pa.
Bot. Tidsskr. [Copenhagen]	Botanisk Tidsskrift. København.
Bot. Zhur. S.S.S.R. (Jour. Bot. de l'U.R.S.S.)	Botanicheskii Zhurnal. Leningrad.
Boyce Thompson Inst. Contrib.	Boyce Thompson Institute. Yonkers, N. Y. Contribution. Professional Paper.
Bragantia [Brazil]	Bragantia. Sao Paulo, Brazil.
Brit. Grassland Soc. Jour.	British Grassland Society Journal. Belfast, Northern Ireland.
Brussels Mus. Roy. d'Hist. Nat. Bul.	Musée Royal d'Histoire Naturelle. Brussels. Bulletin.
Butler Univ. Bot. Studies	Butler University. Botany Laboratories. Butler University Botanical Studies. Indianapolis.

Calif. Fish and Game	California Fish and Game. Department of Natural Resources, Division of Fish and Game. Sacramento.
Cambridge Phil. Soc. Biol. Rev.	Cambridge Philosophical Society. London. Biological Reviews.
Canad. Ent.	Canadian Entomologist. Guelph, Ont.
Canad. Jour. Anim. Sci.	Canadian Journal of Animal Science. Canada.
Canad. Jour. Plant Sci.	Canadian Journal of Plant Science. Ottawa.
Canad. Jour. Res. Sect. C., Bot. Sci.	Canadian Journal of Research. Section C. Botanical Sciences.
Canad. Jour. Zool.	Canadian Journal of Zoology. Ottawa.
Ceylon Jour. Sci. Sect. A., Bot.	Ceylon Journal of Science. Colombo. Section A. Botany.
Chron. Bot. [Leiden]	Chronica Botanica. Leiden, The Netherlands.
Colo. Expt. Sta. Tech. Bul.	Colorado State College, Colorado Experiment Station. Fort Collins, Colo. Technical Bulletin.
Conn. (State) Agr. Expt. Sta. Bul.	Connecticut Agricultural Experiment Station. New Haven. Bulletin.
Copeia	Copeia. Ann Arbor, Mich.
Current Sci. [India]	Current Science. Indian Institute of Science. Bangalore.
[Czechoslovakia] Min. Zeměděl. Sborn.	Czechoslovakia. Ministerstva Zemedelstvi. Prague. Sbornick Výzkumných Ústavú Zemedelských.
Das Grünland [Bonn]	Das Grünland. Bonn, Germany.
Deut. Bot. Gesell. Ber. [Jena]	Deutschen Botanische Gesellschaft. Berichte. Jena.
Diss. Abs.	Dissertation Abstracts. Ann Arbor, Mich.
Duke Univ. Forestry Bul.	Duke University. Forestry Bulletin. Durham, N. C.
East African Agr. and Forestry Res. Organ. Rpt.	East African Agriculture and Forestry Research Organization. Kikuyu, Kenya.
East African Agr. Jour.	East African Agricultural Journal. Kenya, Tanganyika, Uganda and Zanzibar. Nairobi, Kenya Colony.
Ecol. Monog.	Ecological Monographs. Ecological Society of America. Durham, N. C.
Ecol. Soc. Amer. Bul.	Ecological Society of America. Bulletin. Urbana, Ill.
Ecology	Ecology. Brooklyn Botanical Garden, Brooklyn, N. Y.
Ekologia Polska, Ser. A.	Ekologia polska. Warsaw, Poland. Series A.
Empire Forestry Rev.	Empire Forestry Review. London, England.
Empire Jour. Expt. Agr.	Empire Journal of Experimental Agriculture. London.
Ent. Soc. Amer. Ann.	Entomological Society of British Columbia. Proceedings. Victoria.
Evolution	Evolution; International Journal of Organic Evolution. Chicago, Ill.
Expt. Husb. [London]	Experimental Husbandry. London, England.
Forestry [London]	Forestry. Society of Foresters of Great Britain. London.

Forestry Chron. [Canada]	Forestry Chronicle. Knowlton, Quebec.
Forest Sci.	Forest Science. Washington, D. C.
Forschungsdienst [Germany]	Der Forschungsdienst, Neue Folge der Deutschen Landwirtschaftlichen Rundschau. Neudamm and Berlin.
Forstwiss. Centbl. [Berlin]	Forstwissenschaftliches Centralblatt. Berlin.
Franklin Inst. Jour.	Franklin Institute of the State of Pennsylvania. Journal. Philadelphia.
Ga. Expt. Sta. Tech. Bul.	Georgia Experiment Station. Technical Bulletin. Athens.
Hawaii. Planters Rec.	Hawaiian Planters Record. Honolulu.
Herb. Abs.	Herbage Abstracts. Commonwealth Bureau of Pasture and Field Crops, Hurley, England.
Hilgardia	Hilgardia. California Agricultural Experiment Station. Berkeley, Calif.
Human Biol.	Human Biology; a Record of Research. Baltimore.
Hurley Grassland Res. Inst. Expt. Prog.	Hurley, England. Grassland Research Institute. Experiments in Progress.
Idaho Univ. Forest, Range and Wildlife Expt. Sta. Res. Note	Idaho. University. Forest, Range and Wildlife Experiment Station, Moscow. Research Notes.
Ill. Agr. Expt Sta. Bul.	Illinois. University. Agricultural Experiment Station. Urbana. Bulletin.
Ill. Biol. Monog.	Illinois Biological Monographs, Urbana.
Ill. State Acad. Sci. Trans.	Illinois State Academy of Science. Transactions. Springfield.
Imp. Bur. Pastures and Forage Crops, Herbage Rev. (or Bul.)	Imperial Bureau of Pastures and Forage Crops. Cambridge, England. Bulletin or Herbage Reviews.
Imp. Bur. Plant Breeding and Genet. Tech. Commun.	Imperial Bureau of Plant Breeding and Genetics, Technical Communication. Cambridge, England.
Imp. Bur. Plant Genet., Herbage Plants Bul. (or Herbage Rev.)	Imperial Bureau of Plant Genetics. Herbage Plants. Aberystwyth, Wales. Bulletin or Herbage Reviews.
Imp. Council Agr. Res. Misc. Bul. [India]	Imperial Council of Agricultural Research India. Miscellaneous Bulletin.
Indian Acad. Sci. Proc. Sec. B	Indian Academy of Sciences. Proceedings Bangalore. Section B.
Indian Bot. Soc. Jour.	Indian Botanical Society. Journal. Madras.
Indian Forester	Indian Forester. Lahore.
Indian Jour. Agr. Sci.	Indian Journal of Agricultural Science. Delhi.
Indian Jour. Agron.	Indian Journal of Agronomy. New Delhi.
Indian Jour. Statis.	Indian Journal of Statistics. Calcutta.
Indian Jour. Vet. Sci. and Anim. Husb.	Indian Journal of Veterinary Science and Animal Husbandry. London.
Indian Sci. Cong. Proc.	Indian Science Congress. Proceedings. Calcutta.
Indian Soc. Agr. Statis. Jour.	Indian Society of Agricultural Statistics Journal. New Delhi.

Inst. Internatl. de Statis. Bul. [The Hague]	Institut International de Statistique, The Hague, Netherlands. Bulletin.
Internatl. Bot. Cong. Proc.	Proceedings of the International Botanical Congress.
Internatl. Grassland Cong. Proc.	Proceedings of the International Grassland Congress.
Internatl. Jour. Appl. Radiation and Isotopes	International Journal of Applied Radiation and Isotopes. New York, N. Y.
Iowa Agr. Expt. Sta. Res. Bul.	Iowa State College of Agricultural and Mechanic Arts. Ames. Agricultural Experiment Station. Research Bulletin.
Iowa State Col. Jour. Sci.	Iowa State College of Agriculture and Mechanic Arts. Ames. Journal of Science.
Irish Forestry	Irish Forestry. Dublin, Ireland.
Jap. Jour. Ecol.	Japanese Journal of Ecology.
Jour. Agr. Res.	Journal of Agricultural Research. Published by the U.S. Department of Agriculture, with the cooperation of the Association of Land-Grant Colleges. Washington, D.C.
Jour. Agr. Sci. [England]	Journal of Agricultural Science. London.
Jour. Agr. Univ. Puerto Rico	Journal of Agriculture of the University of Puerto Rico. Rio Piédras.
Jour. Anim. Ecol. [London]	Journal of Animal Ecology. London.
Jour. Anim. Sci.	Journal of Animal Science. Menasha, Wis.
Jour. Dairy Sci.	Journal of Dairy Science. Lancaster, Pa.
Jour. Dent. Res.	Journal of Dental Research. New York.
Jour. Ecol. [London]	Journal of Ecology. London.
Jour. Econ. Ent.	Journal of Economic Entomology. Amherst, Mass.
Jour. Farm Econ.	Journal of Farm Economics. Menasha, Wis.
Jour. Forestry	Journal of Forestry. Washington, D.C.
Jour. Gen. Microbiol. [London]	Journal of General Microbiology. London, England.
Jour. Genet. [London]	Journal of Genetics. London.
Jour. Mammal.	Journal of Mammalogy. Ann Arbor, Mich.
Jour. Range Mangt.	Journal of Range Management. Baltimore, Md.
Jour. Soil and Water Conserv.	Journal of Soil and Water Conservation.
Jour. Wildlife Mangt.	Journal of Wildlife Management. Menasha, Wis.
K. Vetensk. Akad. Nobelinst. Meddel. [Uppsala]	Kungl. Vetenskapsakademiens Nobel-institut. Meddelanden. Uppsala.
Kans. Acad. Sci. Trans.	Kansas Academy of Science. Topeka. Transactions.
Kans. Univ. Sci. Bul.	Kansas University. Lawrence. Science Bulletin.
Ky. Agr. Expt. Sta. Bul.	Kentucky Agricultural Experiment Station. University of Kentucky. Lexington. Bulletin.
Kyushu Imp. Univ., Faculty Sci. Mem.	Kyushu Imperial University. Faculty of Science. Memoirs.
Landbouwk. Tijdschr. [The Hague]	Landbouwkundig Tijdschrift. The Hague.

Lima, Peru, Estac. Expt. Agr. de La Molina, Bol.	Estación Experimental Agricola de La Molina. Lima, Peru. Boletin.
Linn. Soc. London, Proc.	Linnean Society of London Proceedings. London, England.
[London] Phys. Soc. Proc.	Physical Society Proceedings. London.
Macdonald Col., McGill Univ. Tech. Bul.	Macdonald College, McGill University. Technical Bulletin.
Madras Agr. Jour.	Madras Agricultural Journal. Coimbatore, So. India.
Maine Univ. Forestry Dept. Tech. Note	Maine University. Forestry Department. Technical Note.
Madroño	Madroño; a West American Journal of Botany Lancaster, Pa.
Malayan Forester	Malayan Forester. Kuala Lumpur.
Mar. Biol. Assoc. United Kingdom Jour.	Marine Biological Association of the United Kingdom Journal. London, England.
[Mex.] Dept. Forest. y de Caza y Pesca Bol.	Mexico. Departamento Forestal y de Caza y Pesca. Boletín. Mexico, D.F.
Mich. Acad. Sci., Arts, and Letters, Papers	Michigan Academy of Science, Arts, and Letters. Lansing. Papers.
Mich. Agr. Expt. Sta. Quart. Bul.	Agricultural Experiment Station of Michigan State College of Agriculture and Applied Science. East Lansing. Quarterly Bulletin.
Mich. Univ. Lab. Vert. Biol. Contrib.	Michigan University. Laboratory of Vertebrate Biology Contributions.
Mont. Acad. Sci. Proc.	Montana Academy of Sciences Proceedings. Bozeman.
Mont. Agr. Expt. Sta. Mim. Cir. (or Bul.)	Montana Agricultural Experiment Station, Bozeman. Mimeograph circular (or Bulletin).
Montes [Madrid]	Montes. Madrid, Spain.
Montreal Univ. Inst. Bot. Contrib.	Montreal, Canada. Université. Institut Botanique. Contributions.
N. C. Agr. Expt. Sta. Tech. Bul.	Agricultural Experiment Station of the North Carolina State College of Agriculture and Engineering and North Carolina Department of Agriculture, cooperating. Raleigh. Technical Bulletin.
Natl. Acad. Sci. Proc.	National Academy of Sciences. Washington, D.C. Proceedings.
Natl. Joint Com. Fert. Appl. Proc.	National Joint Committee on Fertilizer Application Proceedings, Washington, D.C.
Natl. Res. Council. Bul.	National Research Council. Bulletin.
Nature [London]	Nature. London.
Naturf. Gesell. in Bern, Mitt.	Naturforschende Gesellschaft in Bern. Mitteilungen.
Nebr. Agr. Expt. Sta. Res. Bul.	Nebraska University Agricultural Experiment Station. Research Bulletin.
Netherlands Jour. Agr. Sci.	Netherlands Journal of Agricultural Science.
Nev. Agr. Expt. Sta., Bul.	Nevada University. Agricultural Experiment Station. Reno. Bulletin.
New Phytol. [London]	New Phytologist. London.
New Zeal. Jour. Agr.	New Zealand Journal of Agriculture. Wellington.

New Zeal. Jour. Forestry	New Zealand Journal of Forestry.
New Zeal. Jour. Sci. and Technol.	New Zealand Journal of Science and Technology. Wellington.
New Zeal. Jour. Sci. and Technol. Sec. B.	New Zealand Journal of Science and Technology. Christchurch. Section B.
Nord. Jordbrugsforsk. [Sweden]	Nordisk Jordbrugsforskning. København.
Norske Skogsforsøksv. Meddel. [Oslo]	Norske Skogforsøksvaesen. Meddelelser. Utgit av Skogforsøksvaesenet. Oslo.
North Amer. Wildlife Conf. Trans.	North American Wildlife Conference Transactions. Washington, D.C.
North. Ireland Min. Agr. Res. and Expt. Rec.	Northern Ireland. Ministry of Agriculture. Research and Experimental Record. Belfast.
Northwest Sci.	Northwest Science. Cheney, Wash.
Növénytermelés [Budapest]	Növénytermelés (Crop Production). Budapest, Hungary.
Nutr. Soc. Proc. [London]	Nutrition Society Proceedings. London, England.
NYT Mag. [Oslo]	NYT Magazin for Naturvidenskaberne. Oslo.
Ohio Jour. Sci.	Ohio Journal of Science. Columbus.
Oikos [Copenhagen]	Oikos, acta ecologia scandinavica. Copenhagen, Denmark.
Okla. Acad. Sci. Proc.	Oklahoma Academy of Science Proceedings. (University of Oklahoma Bulletin). Norman, Okla.
Onderstepoort Jour. Vet. Sci. and Anim. Indus.	Onderstepoort Journal of Veterinary Science and Animal Industry. Pretoria.
Osaka Imp. Univ., Inst. Polytech. Jour. Ser. D.	Osaka, Japan. Imperial University. Institute of Polytechnics Journal. Series D. Biology.
Pflanzenbau [Leipzig]	Pflanzenbau; Monatsschrift für den Gesamten Acker- und Planzenbar und das Pflanzenbauliche Versuchswesen. Leipzig. (Title varies.)
Phys. Rev.	Physical Review. New York.
Plant and Soil [The Hague]	Plant and Soil; International Journal of Plant Nutrition, Plant Chemistry, Soil Microbiology and Soil-borne Plant Diseases. The Hague, Netherlands.
Portug. Acta Biol. Ser. B.	Portugaliae Acta Biologica. Series B.
Poultry Sci.	Poultry Science. Menasha, Wis.
Problemy Zhivotnovodstva [Moskva]	Problemy Zhivotnovodstva. All-Union Scientific Institute of Animal Husbandry. Moskva.
Psychometrika	Psychometrika
Rev. Mod. Phys.	Reviews of Modern Physics. American Physical Society and American Institute of Physics. New York.
Rio de Janeiro, Jard. Bot. Arq.	Rio de Janeiro. Jardim Botanico Arquivos. Brazil.
Rocz. Nauk Rolnicz. i Lésnych (Polish Agr. and Forest Ann.)	Roczniki Nauk Rolniczych i Lésnych. Poznań, Poland.
Roy. Agr. Soc. England Jour.	Royal Agricultural Society of England. London. Journal.

Roy. Soc. Canada, Proc. and Trans., Sec. 5.	Royal Society of Canada. Proceedings and Transactions. Ottawa, Toronto, and London.
Roy. Soc. London, Phil. Trans., Ser. B.	Royal Society of London. Philosophical Transactions. Series B. Biological.
Roy. Soc. Queensland, Proc.	Royal Society of Queensland. Proceedings. Brisbane.
Roy. Soc. So. Africa, Cape Town, Trans.	Royal Society of South Africa. Transactions. Cape Town and London.
Roy. Soc. Victoria, Proc.	Royal Society of Victoria. Proceedings. Melbourne.
Roy. Statis. Soc. Jour.	Royal Statistical Society Journal. London.
Sankhyā: Indian Jour. Statis.	Sankhyā; Indian Journal of Statistics. Calcutta.
Sanrin (Forestry) Dai-Nippon Sanrinkwai-hô (Jap. Forestry Soc. Jour.)	Sanrin (Forestry) Dai-Nippon Sanrinkwai-hô. Journal of the Japanese Society of Forestry. Tokyo.
Schweiz. Landw. Monatsh. [Bern]	Schweizerische Landwirtschaftliche Monatshefte. Bern.
Schweiz. Ztschr. f. Forstw. [Bern]	Schweizerische Zeitschrift für Forstwesen. Bern.
Sci. Agr. [Ottawa]	Scientific Agriculture. La Revue Agronomique Canadienne. Ottawa.
Sci. Monthly	Scientific Monthly. New York.
Science	Science. New York.
Skogen [Stockholm]	Skogen. Svenska Skogsvårdsföreningen. Stockholm.
So. African Jour. Sci.	South African Journal of Science. Johannesburg.
Soc. Bot. de France Bul.	Société Botanique de France. Bulletin. Paris.
Soc. Bot. de Genéve Bul.	Société Botanique de Genéve. Bulletin. Geneva.
Soc. Vaud. des Sci. Nat. Bul. [Switz.]	Société Vaudoise des Sciences Naturelles. Lausanne. Bulletin.
Soil Sci.	Soil Science. Baltimore.
Soil Sci. Soc. Amer. Proc.	Soil Science Society of America. Proceedings. Ann Arbor, Mich.
South. Pasture and Forage Crop Impr. Conf. Rpt.	Southern Pasture and Forage Crop Improvement Conference. Report. Beltsville, Md.
Sovet. Bot. [Moskva]	Sovetskaîa Botanika. Moskva and Leningrad.
Svensk Bot. Tidskr. [Stockholm]	Svensk Botanisk Tidskrift. Stockholm.
Svenska Mosskulturför. Tidskr. [Sweden]	Svenska Mosskulturförening. Tidskrift. Jönköping, Sweden.
Svenska Skogsvårdsför. Tidskr. [Stockholm]	Svenska Skogsvårdsföreningens Tidskrift. Stockholm.
Sveriges Utsädesför. Tidskr. [Sweden]	Sveriges Utsädesförenings Tidskrift. Svalöf, Sweden.
Sylwan [Warsaw]	Sylwan. (Polskie naukowe towarzystwo leśne). Warsaw, Poland.
Tasmanian Jour. Agr.	Tasmania. Department of Agriculture. Tasmanian Journal of Agriculture. Hobart, Tasmania.

Tidsskr. for Planteavl [Copenhagen]	Tidsskrift for Planteavl. København.
Tidsskr. for Skogbruk [Oslo]	Tidsskrift for Skogbruk. Oslo.
Tohoku Univ. Inst. Agr. Res. Bul.	Tohoku University. Institute of Agricultural Research. Nogaku Kenkyujo Iho. Bulletin.
Tokyo Natl. Inst. Agr. Sci. Bul. Ser. A.	Tokyo, Japan. National Institute of Agricultural Sciences, Nishigahara. Bulletin Series A.
Tokyo Univ. Forests Bul.	Tokyo University Forests, Bunkyo-ku, Tokyo. Bulletin.
Torrey Bot. Club Bul.	Torrey Botanical Club. Menasha, Wis. Bulletin.
Trop. Agr. [Trinidad]	Tropical Agriculture. Imperial College of Tropical Agriculture. St. Augustine, Trinidad.
U.S. Dept. Agr. Bul. (or Cir., Misc. Pub., Tech. Bul.)	United States Department of Agriculture. Washington, D.C. Bulletin (or Circular, Miscellaneous Publication, Technical Bulletin).
U.S. Forest Serv. South. Forest Expt. Sta. Occas. Paper	United States Forest Service. Southern Forest Experiment Station, New Orleans, La. Occasional Papers.
U.S. Monthly Weather Rev.	United States Weather Bureau. Monthly Weather Review. Washington, D.C.
Utah Acad. Sci., Arts and Letters Proc.	Utah Academy of Sciences, Arts and Letters. Proceedings. Salt Lake City.
Utah Agr. Expt. Sta. Bul.	Utah Agricultural Experiment Station. Utah State Agricultural College. Logan, Utah. Bulletin.
Utah Juniper	Utah Juniper. Utah Foresters. Utah State Agricultural College. Logan, Utah
Vegetatio [The Hague]	Vegetatio Acta Geobotanica. The Hague, Netherlands.
Valtion Maatalouskoet. Julkaisu. [Finland]	Statens Lantbruksförsöksverksamhet Vetenskapliga. Publikationer. Helsingfors.
Victoria Dept. Agr. Jour.	Victoria Department of Agriculture. Melbourne. Journal.
[Wageningen] Landbouwhoogesch. Meded.	Landbouwhoogeschool. Wageningen, The Netherlands. Mededeelingen.
Wageningen Rijksinst. v. Rassenonderzoek van landbgewassen Meded.	Wageningen, Netherlands. Rijksinstituut voor rassenonderzoek van landbouwgewassen. Mededelingen.
Wash. Acad. Sci. Jour.	Washington Academy of Science. Menasha, Wis. Journal.
Wash. Agr. Expt. Sta. Bul.	State College of Washington. Agricultural Experiment Station. Pullman, Wash. Bulletin.
Welsh Plant Breeding Sta., Aberystwyth, Rpt.	Welsh Plant Breeding Station. Aberystwyth. Report.
Ztschr. f. Acker- u. Pflanzenbau [Berlin]	Zeitschrift für Acker- und Pflanzenbau. Berlin.
Ztschr. f. Landw. Vers.- u. Untersuchw., Rostock.	Zeitschrift für Landwirtschaftliches Versuchs- und Untersuchungswesen. Rostock.